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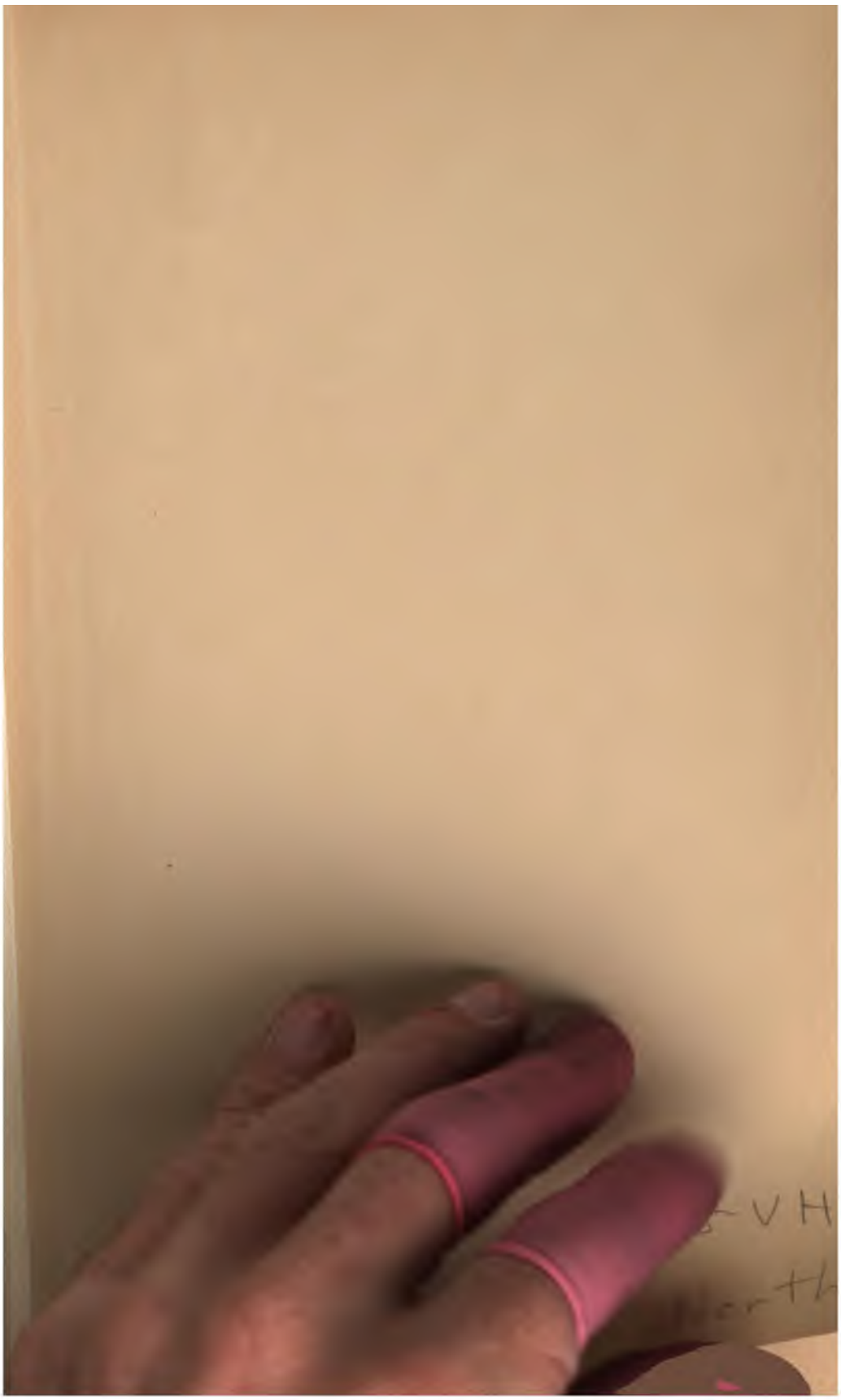
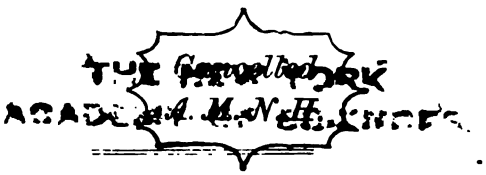


NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.



TRANSACTIONS.

VOL. XXVIII.

1878-79.

NEWCASTLE-UPON-TYNE: A. REID, PRINTING COURT BUILDINGS, AKENSIDE HILL

1879.

'11.2919, July 11

NEWCASTLE-UPON-TYNE:

ANDREW REID, PRINTING COURT BUILDINGS, AKENSIDE HILL.

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Report.

THE Council having duly estimated the present position of the Institute, after a lengthened period of great commercial depression, consider that the members have great reason to be gratified. Notwithstanding that there has been a falling off in the number of members and a consequent decrease in the receipts from subscriptions, the actual receipts are slightly in excess of those of last year, and, the expenditure having been judiciously limited, the balance at the bankers has increased.

With regard to the useful work executed, they may mention that much time was occupied in settling, with great care, the principles upon which the Ventilators' Committee should continue their researches, and the mode in which the experiments should be conducted; but a satisfactory system has at length been arrived at for prosecuting this important inquiry into the merits of the various classes of ventilators before the public, and the Committee have reported progress.

There have been no excursions away from the district during the year, but a very instructive visit was made to the Browney Colliery, on the invitation of Messrs. Bell Brothers, where they were received by Mr. A. L. Steavenson, the Chief Engineer of the Company, and inspected an apparatus for saving labour in the manufacture of coke, the invention of Messrs. Bell, Harle, and Cleugh.

The Proceedings have reached their usual high standard of excellence.

Mr. Kendall has contributed a most complete and exhaustive description of the Hematite Deposits of West Cumberland, which is especially valuable, as it is a district which has not been previously treated of in the Transactions.

The other descriptive papers have been one by Mr. A. R. Sawyer, "On the Saarbrücken Coal-field," and another by Professor Lebour "On the Coal and Limestone Series of Northumberland."

The papers more especially connected with the safety of mines were an exceedingly valuable and interesting communication from Professor Marreco and Mr. Morrison—"On the question as to how far Coal Dust, as it exists in the Atmosphere of Pit Workings, is Explosive, whether free or not from the presence of Gas." This paper, illustrated by experiments

and followed by an exhaustive discussion, forms a valuable addition to our present knowledge of this very important subject. A paper by Mr. E. H. Liveing, describing an elegant and ingenious instrument for the detection of small quantities of gas; a paper by Professor Marreco, describing a self-recording water gauge; the papers "On Rigg and Meiklejon's Coal-Cutting Machine," and "Schmitt's Revolving Spiral Screen," by Mr. D. P. Morison; "On a Supply of Pure Water and Motive Power to Towns," by Mr. Burns; and "On the Mathematical Theory of Amsler's Planimeter," by Professor Aldis, add a mass of valuable information to the year's Proceedings.

Finance Report.

THE Finance Committee have to report that the receipts from all sources for the past year have been £2,138 11s. 10d., being £61 15s. 2d. in excess of those of the previous year, which were £2,076 16s. 8d. This is due partly to the increased value of investments, which has more than counterbalanced the falling off in the amount of the subscriptions received.

The members' subscriptions amounted to £1,709 10s., against £1,783 19s. last year, showing a decrease of £74 9s.

By judicious economy the expenditure has been again brought below the annual receipts, the difference being £58 7s.

The Institute continues to hold 134 shares in the Institute and Coal Trade Chambers' Company, Limited, of the value of £2,680.

G. C. GREENWELL.
WILLIAM COCHRANE.
G. B. FORSTER.
J. B. SIMPSON.

ADVERTISEMENT.

The Institute is not, as a body, responsible for the facts and opinions advanced in the Papers read, and in the Abstracts of Conversations which occurred at the Meetings during the Session.

DR. THE TREASURER IN ACCOUNT

		£	s.	d.
To 750 Original Members, as per List 1878-79:—				
9 of which are Life Members, one having paid this year		20	0	0
741 @ £2 2s.		1,556	2	0
To 17 Ordinary Members, as per List 1878-79:—				
8 @ £2 2s. and 9 @ £3 3s.		45	3	0
To 12 Associate Members, as per List 1878-79, @ £2 2s.		25	4	0
To 9 New Ordinary Members @ £3 3s		28	7	0
To 14 New Associate Members, as per List 1878-79:—				
1 of which paid as Life Member		20	0	0
13 @ £2 2s.		27	6	0
To 151 Old Students, as per List 1878-79:—				
1 do. paid as Member		2	2	0
150 do. at £1 1s.		157	10	0
To 14 New Students, as per List 1878-79, @ £1 1s....		14	14	0
To 14 Subscribing Collieries do.		71	8	0
		1,967	16	0
To Arrears, as per last Balance Sheet	431 11 0			
Deduct—				
Irrecoverable Arrears not inserted in 1878-79 List (Dead Resigned, &c.)	166 19 0			
Actual Arrears to collect 1878-79		264	12	0
		£2,232	8	0

WITH SUBSCRIPTIONS, 1878-79. CR.

		PAID.			UNPAID.		
		£	s.	d.	£	s.	d.
By 601	Original Members paid	1,262	2	0			
By 107	Do. unpaid				224	14	0
By 5	Do. dead, unpaid				10	10	0
By 6	Do. resigned do.				12	12	0
By 22	Do. gone, no address				46	4	0
741							
By 1	Do. paid as Life Member	20	0	0			
By 13	Ordinary Members paid, 8 @ £3 3s., and 5 @ £2 2s...	35	14	0			
By 4	Do. unpaid, 1 @ £3 3s. and 3 @ £2 2s.				9	9	0
17							
By 11	Associate Members paid	23	2	0			
By 1	Do. unpaid				2	2	0
12							
By 9	New Ordinary Members paid	28	7	0			
By 10	New Associate Members paid	21	0	0			
3	Do. unpaid				6	6	0
13							
By 1	Do. paid as Life Member ...	20	0	0			
By 129	Old Students paid	135	9	0			
15	Do. unpaid				15	15	0
2	Do. resigned, unpaid				2	2	0
4	Do. gone, no address...				4	4	0
150							
By 1	Do. paid as Member	2	2	0			
By 14	New Students paid	14	14	0			
By 12	Subscribing Collieries paid	58	16	0			
By 2	Do. unpaid				12	12	0
		1,621	6	0	346	10	0
By Members' Arrears		81	18	0	171	3	0
By Students' Do.		6	6	0	5	5	0
		1,709	10	0	522	18	0
					1,709	10	0
					£2,232	8	0

Audited and Certified,
JOHN G. BENSON & CO.,
PUBLIC ACCOUNTANTS.

Newcastle-on-Tyne,
August 2nd, 1879.

TREASURER IN ACCOUNT WITH THE NORTH OF ENGLAND

Dr. *For the Year ending*

	£	s.	d.
To Balance at Bankers	35	6	0
To Do. in hands of Treasurer	97	3	3
To Do. do. Liquidators of District Bank	12	7	3
To Bequest of the late R. Stephenson, Esq., invested in Shares of the Institute and Coal Trade Chambers Co., Limited	2,000	0	0
To further Amount invested in Shares of the above Company	680	0	0
	2,824	16	6
To Dividend of 8 per cent. on 134 Shares of £20 = £2,680	214	8	0
To Rent of College Class Rooms, less Borough Rates	48	0	1
To Subscriptions for 1878-79 from 601 Old Members (Original) 1,262 2 0			
To Do. do. 1 Old Member, paid as Life Member 20 0 0			
To Do. do. 13 Ordinary Members 35 14 0			
To Do. do. 11 Associate Do. 23 2 0			
To Do. do. 9 New Members (Ordinary) ... 28 7 0			
To Do. do. 10 Do. (Associate) ... 21 0 0			
To Do. do. 1 Do. do. paid as Life Member 20 0 0			
To Do. do. 129 Old Students 135 9 0			
To Do. do. 1 Do. paid as Member... 2 2 0			
To Do. do. 14 New Students 14 14 0			
To Subscribing Collieries, viz.:—			
Ashington 2 2 0			
Haswell 4 4 0			
Hetton 10 10 0			
North Hetton 6 6 0			
Rainton 10 10 0			
Ryhope 4 4 0			
Seghill 2 2 0			
South Hetton and Murton 8 8 0			
Stella 2 2 0			
Throckley 2 2 0			
Wearmouth 4 4 0			
Whitworth 2 2 0			
58 16 0			
To Members' Arrears 81 18 0			
To Students' Do. 6 6 0			
	1,709	10	0
To Sale of Publications, per A. Reid 182 6 9			
Less—10 per cent. Commission 15 13 0			
	166	13	9
	£4,963	8	4

INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

August, 1879. Cr.

	£	s.	d.	£	s.	d.
By Paid A. Reid, Publishing Account	538	9	6			
By Do. Covers for Parts and Stitching	65	2	0			
By Do. Binding and Sewing Volumes	61	18	5			
By Do. Postage	68	19	3			
By Do. Stationery and Circulars	61	12	9			
By Do. Library	36	12	0			
By Do. Insurance and Advertising	7	5	7			
By Do. Borings	58	10	0			
By Do. Hutton Collection of Fossils	92	12	4			
By Do. Reprinting Volume XVII.	260	0	0			
				1,251	1	10
By other Printing and Stationery				2	13	8
By Secretary's Incidental Expenses and Postage				136	3	10
By Sundry Accounts				47	10	8
By Travelling Expenses				16	0	9
By Secretary's Salary				300	0	0
By Assistant's Do.				75	0	0
By Reporter's Do.				12	12	0
By Payments on account of Furnishing				37	6	0
By Rent				73	3	1
By Rates and Taxes				14	8	6
By Fire Insurance				8	15	8
By Water, Coals, and Gas				22	18	5
By Subscription to the Natural History Society				20	0	0
By Burnup & Son				24	11	3
By Watson & Son				5	1	4
By Books for Library, in addition to amount paid A. Reid				9	0	4
By Publications Returned				3	3	0
By Instruments				20	14	6
				2,080	4	10
By Bequest of the late R. Stephenson, Esq., invested in Shares of the Institute and Coal Trade Chambers Co., Limited				2,000	0	0
By further Amount invested in Shares of the above Company				680	0	0
By Balance in hands of Liquidators of District Bank				12	7	3
By Balance at Bankers				166	3	5
By Do. in hands of Treasurer				24	12	10
				£4.963	8	4

Audited and Certified,
JOHN G. BENSON & CO.,
PUBLIC ACCOUNTANTS.

Newcastle-on-Tyne,
August 2nd, 1879.

DR. GENERAL STATEMENT, AUGUST, 1879. CR.

Liabilities.	£	s.	d.
None	"	"	"
Capital	6,633	13	0
	£6,633	13	0

Assets.	£	s.	d.
Balance of Account at Bankers	166	3	5
Balance in hands of Liquidators of District Bank ...	12	7	3
Balance in hands of Treasurer	24	12	10
134 Shares of £20 each in the Institute and Coal Trade Chambers Company, Limited	2,860	0	0
Arrears of Subscriptions	522	18	0
Value of 269 Bound Volumes of Transactions, @ 11s. 6d.	154	13	6
Value of 3,546 Sewn Copies of Transactions, @ 9s. ...	1,595	14	0
Value of sundry Sheets and Plates belonging to Vol. XXVIII., unfinished at this date	250	0	0
Value of 37 Copies of Mr. T. F. Brown's Map of the South Wales Coal-field, @ 5s.	9	5	0
Value of 488 Copies of General Index, @ 3s.	73	4	0
Value of 824 Copies of Fossil Illustrations, at 12s. 6d. ...	515	0	0
Value of 912 Copies of Catalogue, @ 5s.	228	0	0
Value of 407 Copies of Borings and Sinkings, at 5s. ...	101	15	0
Value of 1,500 Copies of Do. in sheets, @ 4s.	300	0	0
	£6,633	13	0

Audited and Certified (Share Certificates produced),

JOHN G. BENSON & CO.,

PUBLIC ACCOUNTANTS.

Newcastle-on-Tyne, August 2nd, 1879.

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The Right Reverend the LORD BISHOP OF DURHAM.
The Very Reverend the DEAN AND CHAPTER OF DURHAM.
WENTWORTH B. BEAUMONT, Esq., M.P.

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Secretary and Treasurer.

THEO. WOOD BUNNING, Neville Hall. Newcastle-on-Tyne.

List of Members.

AUGUST, 1879.

Original Members.

Marked (*) are Life Members.

		ELECTED.
1	ADAMS, G. F., Guild Hall Chambers, Cardiff	Dec. 6, 1873
2	ADAMS, W., Cambridge House, Park Place, Cardiff	1854
3	ADAMSON, DANIEL, Engineering Works, Hyde Junction, Manchester	Aug. 7, 1875
4	ADDY, W. F., Dronfield, near Sheffield	May 6, 1876
5	AITKIN, HENRY, Falkirk, N.B.	Mar. 2, 1865
6	ALLISON, T., Belmont Mines, Guisbro'	Feb. 1, 1868
7	ANDERSON, C. W., Sea View, South Shields	Aug. 21, 1852
8	ANDERSON, WILLIAM, Rainton Colliery, Fence Houses	Aug. 21, 1852
9	ANDREWS, HUGH, Felton Park, Felton, Northumberland	Oct. 5, 1872
10	APPLEBY, C. E., Charing Cross Chambers, Duke Street, Adelphi, London, W.C.	Aug. 1, 1861
11	ARCHER, T., Dunston Engine Works, Gateshead	July 2, 1872
12	ARMSTRONG, SIR W. G., C.B., LL.D., F.R.S., Jesmond, Newcastle-upon-Tyne ... ... (PAST PRESIDENT, *Member of Council*)	May 3, 1866
13	ARMSTRONG, WM., Sen., Pelaw House, Chester-le-Street	Aug. 21, 1852
14	ARMSTRONG, W., Junior, Wingate, Co. Durham	April 7, 1867
15	ARMSTRONG, W. L., Leighs Wood Colliery Co. Ld., Aldridge, nr. Walsall	Mar. 3, 1864
16	ARTHUR, DAVID M. E., Accrington, near Manchester...	Aug. 4, 1877
17	ASHWELL, H., Anchor Colliery, Longton, North Staffordshire ...	Mar. 6, 1862
18	ASHWORTH, JAMES, 56, Upper Duke Street, Southport	Feb. 5, 1876
19	ASHWORTH, JOHN, Jun., 81, Bridge Street, Manchester	Sept. 2, 1876
20	ASQUITH, T. W., Seaton Delaval Colliery, Northumberland	Feb. 2, 1867
21	ATKINSON, J. B., Ridley Mill, Stocksfield-on-Tyne	Mar. 5, 1870
22	ATKINSON, W. N., Chilton Moor, Fence Houses	June 6, 1868
23	AUBREY, R. C., Salisbury Terrace, Garforth, near Leeds	Feb. 5, 1870
24	AUSTINE, JOHN, Cadzow Coal Co., Glasgow	Nov. 4, 1876
25	AYNSLEY, WM., Birtley, Chester-le-Street	Mar. 3, 1873
26	BAGLEY, CHAS. JOHN, Tees Bridge Iron Co., Stockton	June 5, 1875
27	BAILES, GEORGE, Murton Colliery, Sunderland	Feb. 3, 1877
28	BAILES, JOHN, Wingate Colliery, Ferryhill	Sept. 5, 1868
29	BAILES, T., Junior, 41, Lovaine Place, Newcastle-on-Tyne	Oct. 7, 1858
30	BAILES, W., Murton Colliery, Sunderland	April 7, 1877
31	BAILEY, G., St. John's Colliery, Wakefield	June 5, 1869
32	BAILEY, SAMUEL, Perry Barr, Birmingham	June 2, 1859

		ELECTED.
33	BAIN, R. DONALD, Newport, Monmouthshire	Mar. 3, 1873
34	BAINBRIDGE, E., Nunnery Colliery Offices, Sheffield	Dec. 3, 1863
35	BANKS, THOMAS, Leigh, near Manchester	Aug. 4, 1877
36	BARCLAY, A., Caledonia Foundry, Kilmarnock	Dec. 6, 1866
37	BARKUS, WM., 1, St. Nicholas' Buildings, Newcastle-on-Tyne ...	Aug. 21, 1852
38	BARNES, T., Seaton Delaval Office, Quay, Newcastle-on-Tyne ...	Oct. 7, 1871
39	BARRAT, A. J., Ruabon Coal Co., Ruabon	Sept. 11, 1875
40	BARTHOLOMEW, C., Castle Hill House, Ealing, London, W.	Aug. 5, 1853
41*	BARTHOLOMEW, C. W., Blakesley Hall, near Towcester	Dec. 4, 1875
42	BASSETT, A., Tredegar Mineral Estate Office, Cardiff	1854
43	BATES, MATTHEW, Bews Hill, Blaydon-on-Tyne	Mar. 3, 1873
44	BATES, THOMAS, Heddon, Wylam, Northumberland	Mar. 3, 1873
45	BATES, W. J., Old Axwell, Whickham, Gateshead-on-Tyne	Mar. 3, 1873
46	BATEY, JOHN, Newbury Collieries, Coleford, Bath	Dec. 5, 1868
47	BEANLANDS, A., M.A., North Bailey, Durham	Mar. 7, 1867
48	BEAUMONT, JAMES, M.E., Oughtbridge, near Sheffield	Nov. 7, 1874
49	BELL, I. L., M.P., Rounton Grange, Northallerton (VICE-PRESIDENT)	July 6, 1854
50	BELL, JOHN (Messrs. Bell Brothers), Middlesbro'-on-Tees	Oct. 1, 1857
51	BELL, THOMAS, Crosby Court, Northallerton	Sept. 3, 1870
52	BELL, T., Jun. (Messrs. Bell Brothers), Middlesbro'-on-Tees	Mar. 7, 1867
53	BENSON, J. G., Accountant, Newcastle-on-Tyne	Nov. 7, 1874
54	BENSON, T. W., 11, Newgate Street, Newcastle *(Member of Council)*	Aug. 2, 1866
55	BERKLEY, C., Marley Hill Colliery, Gateshead	Aug. 21, 1852
56	BERRYMAN, ROBERT	Aug. 5, 1876
57	BESWICKE, WM., South Parade, Rochdale	Sept. 11, 1875
58	BEWICK, T. J., M. Inst. C.E., F.G.S., Haydon Bridge, Northumberland	April 5, 1860
59	BIDDER, B. P., c/o C. J. Ryland, 3, Small Street, Bristol	May 2, 1867
60	BIGLAND, J., Bedford Lodge, Bishop Auckland	June 4, 1857
61	BINNS, C., Claycross, Derbyshire	July 6, 1854
62	BIRAM, B., Peaseley Cross Collieries, St. Helen's, Lancashire ...	1856
63	BLACK, JAMES, Jun., Portobello Foundry, Sunderland	Sept. 2, 1871
64	BLACK, W., Hedworth Villa, South Shields	April 2, 1870
65	BOLAM, H. G., Little Ingestre, Stafford	Mar. 6, 1875
66	BOLTON, H. H., Newchurch Collieries, near Manchester	Dec. 5, 1868
67	BOOT, J. T., M.E., Westfield House, Sutton, near Mansfield	April 1, 1871
68	BOOTH, R. L., Ashington Colliery, near Morpeth	1864
69	BORRIES, THEO., Lombard Street, Quay, Newcastle-on-Tyne	April 11, 1874
70	BOURNE, PETER, 39, Rodney Street, Liverpool	1854
71	BOURNE, THOS. W., Broseley, Salop	Sept. 11, 1875
72	BOYD, E. F., Moor House, Fence Houses (PAST PRES., *Mem. of Council*)	Aug. 21, 1852
73	BOYD, R. F., Moor House, Fence Houses ...*(Member of Council)*	Nov. 6, 1869
74	BOYD, WM., 74, Jesmond Road, Newcastle-on-Tyne	Feb. 2, 1867
75	BRADFORD, GEO., Etherley, Bishop Auckland	Oct. 11, 1873
76	BRECKON, J. R., Park Place, Sunderland	Sept. 3, 1864
77	BRETTELL, T., Mine Agent, Dudley, Worcestershire	Nov. 3, 1866
78	BROGDEN, J.	1861
79	BROMILOW, WM., Queen's Road, Southport, Lancashire	Sept. 2, 1876

ELECTED.

80 BROWN, E., 79, Clayton Street, Newcastle-on-Tyne ... ... Mar. 7, 1874
81 BROWN, JOHN, Littleworth House, Hednesford, near Stafford ... Oct. 5, 1854
82 BROWN, J. N., 56, Union Passage, New Street, Birmingham ... 1861
83 BROWN, THOS. FORSTER, Guild Hall Chambers, Cardiff
(Member of Council) 1861
84 BROWNE, B. C., Asso. M.I.C.E., No. Granville Road, Jesmond, N'castle Oct. 1, 1870
85 BRUTON, W., Whitwood, Normanton, Streethouse Colls., nr. Normanton Feb. 6, 1869
86 BRYHAM, WILLIAM, Rosebridge Colliery, Wigan ... ... Aug. 1, 1861
87 BRYHAM, W., Jun., Douglas Bank Collieries, Wigan ... ... Aug. 3, 1865
88 BUNNING, THEO. WOOD, Neville Hall, Newcastle-on-Tyne
(Secretary and Treasurer) 1864
89* BURNS, DAVID, C.E., Brookside, Haltwhistle ... ... May 5, 1877
90 BURROWS, JAMES, Douglas Bank, Wigan, Lancashire... ... ... May 2, 1867
91 BURROWS, J. S., Green Hall, Atherton, Manchester ... ... Oct. 11, 1873

92 CALDWELL, GEORGE, Moss Hall Colliery, near Wigan ... ... Mar. 6, 1869
93 CAMPBELL, W. B., Consulting Engineer, Grey Street, Newcastle ... Oct. 7, 1876
94 CARR, WM. COCHRAN, South Benwell, Newcastle-on-Tyne ... ... Dec. 3, 1857
95 CARRINGTON, T., Jun., High Hazels, Darnal, near Sheffield ... ... Aug. 1, 1861
96 CATRON, J., Brotton Hall, Saltburn-by-the-Sea ... ... Nov. 3, 1866
97 CHADBORN, B. T., Pinxton Collieries, Alfreton, Derbyshire 1864
98 CHADWICK, W. H., Bank Colliery, Little Hulton, nr. Bolton, Lancashire Dec. 4, 1875
99 CHAMBERS, A. M., Thorncliffe Iron Works, near Sheffield ... ... Mar. 6, 1869
100 CHAPMAN, M., Plashetts Colliery, Northumberland ... ... Aug. 1, 1868
101 CHARLTON, E., Evenwood Colliery, Bishop Auckland ... ... Sept. 5, 1868
102 CHARLTON, F., C.E., Moot Hall, Newcastle-on-Tyne ... ... Sept. 2, 1871
103 CHARLTON, GEORGE, Washington Colliery, Co. Durham ... ... Feb. 6, 1875
104 CHECKLEY, THOMAS, M.E., Lichfield Street, Walsall ... ... Aug. 7, 1869
105 CHEESMAN, I., Throckley Colliery, Newcastle-on-Tyne ... ... Feb. 1, 1873
106 CHEESMAN, W. T., Wire Rope Manufacturer, Hartlepool ... ... Feb. 5, 1876
107 CHILDE, ROWLAND, Wakefield, Yorkshire ... ... May 15, 1862
108 CLARENCE, THOMAS, Elswick Colliery, Newcastle-on-Tyne ... ... Dec. 4, 1875
109 CLARK, C. F., Garswood Coal and Iron Co., near Wigan ... ... Aug. 2, 1866
110 CLARK, G., Chesterton Coal & Iron Co. Ld., Chesterton, No. Staffords. Dec. 7, 1867
111 CLARK, G., Jun., Southwick Engine Works, Sunderland ... ... Dec. 6, 1873
112 CLARK, R. B., Marley Hill, near Gateshead ... ... May 3, 1873
113 CLARK, W., M.E., The Grange, Teversall, near Mansfield ... ... April 7, 1866
114 CLARKE, WILLIAM, Victoria Engine Works, Gateshead ... ... Dec. 7, 1867
115 CLIFFT, J. H., 26, Devonshire Street, High Broughton, Manchester... May 6, 1876
116 COCHRANE, B., Aldin Grange, Durham ... ... Dec. 6, 1866
117 COCHRANE, C., The Grange, Stourbridge ... ... June 3, 1857
118 COCHRANE, W., St. John's Chambers, Grainger Street West, Newcastle
(VICE-PRESIDENT) 1859
119 COCKBURN, G., 8, Summerhill Grove, Newcastle-on-Tyne ... ... Dec. 6, 1866
120 COCKBURN, W., Huntcliffe House, Saltburn-by-the-Sea ... ... Oct. 1, 1859
121 COE, W. S., Newchapel Colliery, Tunstall ... ... Feb. 5, 1876
122 COKE, R. G., Brimington Hall, near Chesterfield ... ... May 5, 1856

ELECTED

123 COLE, RICHARD, Walker Colliery, near Newcastle-on-Tyne ... ... April 5, 1873
124 COLE, ROBERT HEATH, Scholar Green, Stoke-upon-Trent ... ... Feb. 5, 1876
125 COLE, W. R., Broomfield, Jesmond, Newcastle-on-Tyne ... ... Oct. 1, 1857
126 COLLIS, W. B., Swinford House, Stourbridge, Worcestershire ... June 6, 1861
127 COOK, J., Jun., Washington Iron Works, Gateshead ... ... May 8, 1869
128 COOKE, JOHN, North Brancepeth Colliery, near Durham ... ... Nov. 1, 1860
129 COOKSEY, JOSEPH, West Bromwich, Staffordshire ... ... Aug. 3, 1865
130 COOPER, P., Thornley Colliery Office, Ferryhill... ... ... Dec. 3, 1857
131 COOPER, R. E., C.E., 1, Westminster Chambers, Victoria Street, London Mar. 4, 1871
132 COOPER, T., Rosehill, Rotherham, Yorkshire ... ... April 2, 1863
133 COPE, JAMES, Port Vale, Longport, Staffordshire ... ... Oct. 5, 1872
134 CORBETT, V. W., Seaton House, Seaham Harbour *(Mem. of Council)* Sept. 3, 1870
135 CORBITT, M., Wire Rope Manufacturer, Teams, Gateshead ... ... Dec. 4, 1875
136 COULSON, F., Shamrock House, Durham ... ... Aug. 1, 1868
137 COULSON, W., Shamrock House, Durham ... ... Oct. 1, 1852
138 COWEN, JOS., M.P., Blaydon Burn, Newcastle-on-Tyne ... ... Oct. 5, 1854
139 COWEY, JOHN, Wearmouth Colliery, Sunderland ... ... Nov. 2, 1872
140 COWLISHAW, J., Thorncliffe, &c., Collieries, near Sheffield ... ... Mar. 7. 1867
141 COX, JOHN H., 10, St. George's Square, Sunderland ... ... Feb. 6, 1875
142*COXE, E. B., Drifton, Jeddo, P. O. Luzerne Co., Penns., U.S. ... Feb. 1, 1873
143 COXON, HENRY, Quay, Newcastle-on-Tyne ... ... Sept. 2, 1871
144 COXON, S. B., Usworth Colliery, Washington Station, Co. Durham *(Member of Council)* June 5, 1856
145 CRAIG, W. Y., Palace Chambers, St. Stephen's, Westminster, London Nov. 3, 1866
146 CRAWFORD, T., Littletown Colliery, near Durham ... ... Aug. 21, 1852
147 CRAWFORD, T., 3, Grasmere Street, Gateshead-on-Tyne ... ... Sept. 3, 1864
148 CRAWFORD, T., Jun. Littletown Colliery, near Durham ... ... Aug. 7, 1869
149 CRAWSHAY, E., Gateshead-on-Tyne ... ... Dec. 4, 1869
150 CRAWSHAY, G., Gateshead-on-Tyne ... ... Dec. 4, 1869
151 CROFTON, J, G., Esh Colliery, Durham ... ... Feb. 7, 1861
152 CRONE, E. W., Killingworth Hall, near Newcastle-on-Tyne ... ... Mar. 5, 1870
153 CRONE, J. R., Tow Law, *via* Darlington ... ... Feb. 1, 1868
154 CRONE, S. C., Killingworth Colliery, Newcastle 1853
155 CROSS, JOHN, 78, Cross Street, Manchester ... ... June 5, 1869
156 CROUDACE, C. J., The Laurels, Newton, by Chester ... ... Nov. 2, 1872
157 CROUDACE, JOHN, West House, Haltwhistle ... ... June 7, 1873
158 CROUDACE, THOMAS, Lambton Lodge, New South Wales 1862

159 DABURON, Mons., Ingénieur aux Mines de Lens, Pas de Calais ... May 1, 1875
160 DAGLISH, JOHN, Marsden, South Shields ... ... Aug. 21, 1852
161 DAGLISH, W. S., Solicitor, Newcastle-on-Tyne ... ... July 2, 1872
162 DAKERS, J., Chilton Colliery, Ferryhill ... ... April 11, 1874
163 DALE, DAVID, West Lodge, Darlington ... ... Feb. 5, 1870
164 D'ANDRIMONT, T., Liége, Belgium ... ... Sept. 3, 1870
165 DANIEL, W., 37, Camp Road, Leeds ... ... June 4, 1870
166 DARLING, FENWICK, South Durham Colliery, Darlington ... ... Nov. 6, 1875
167 DARLINGTON, JOHN, 2, Coleman Street Buildings, Moorgate Street, Great Swan Alley, London ... ... April 1, 1865

ELECTED.

168 DARLINGTON, J., Black Park Colliery Co. Limited, Ruabon ... ... Nov. 7, 1874
169 DAVEY, HENRY, C.E., Leeds ... ... Oct. 11, 1873
170 DAVIDSON, JAMES, Newbattle Colliery, Dalkeith 1854
171 DAVIS, DAVID, Coal Owner, Maesyffynon, Aberdare ... ... Nov. 7, 1874
172 DAVISON, GEORGE ... ... Mar. 4, 1876
173 DAY, W. H., Eversley Garth, So. Milford ... ... Mar. 6, 1869
174 DEACON, MAURICE ... ... Sept. 11, 1875
175 DEES, R. R., Solicitor, Newcastle-on-Tyne ... ... Oct. 7, 1871
176 DICKINSON, G. T., Wheelbirks, Northumberland ... ... July 2, 1872
177 DICKINSON, R., Coal Owner, Shotley Bridge, Co. Durham ... ... Mar. 4, 1871
178 DIXON, D. W., Brotton Mines, Saltburn-by-the-Sea ... ... Nov. 2, 1872
179 DIXON, NICH., Dudley Colliery, Dudley, Northumberland ... ... Sept. 1, 1877
180 DIXON, R., Wire Rope Manufacturer, Teams, Gateshead ... ... June 5, 1875
181 DOBSON, W., 14, Ashfield Terrace West, Newcastle-on-Tyne ... ... Sept. 4, 1869
182 DODD, B., Bearpark Colliery, near Durham ... ... May 3, 1866
183 DODDS, J., M.P., Stockton-on-Tees ... ... Mar. 7, 1874
184 DOUGLAS, C. P., Consett House, Consett, Co. Durham ... ... Mar. 6, 1869
185 DOUGLAS, T., Peases' West Collieries, Darlington ... ... Aug. 21, 1852
186 DOUTHWAITE, T., Merthyr Vale Colliery, Merthyr Tydvil ... ... June 5, 1869
187 DOVE, G., Viewfield, Stanwix, Carlisle ... ... July 2, 1872
188 DOWDESWELL, H., Butterknowle Colliery, *via* Darlington ... ... April 5, 1873
189 DYSON, GEORGE, Middlesborough ... ... June 2, 1866
190 DYSON, O., Houghton Main Colliery, Darfield, near Barnsley ... Mar. 2, 1872

191 EASTON, J., Nest House, Gateshead 1853
192 ECKERSLEY, NATHANIEL, Standish Hall, Wigan ... ... Sept. 2, 1876
193 EDDISON, ROBERT W., Steam Plough Works, Leeds ... ... Mar. 4, 1876
194 ELAND, J. S., Accountant, Newcastle-on Tyne ... ... Nov. 7, 1874
195 ELLIOT, SIR GEORGE, BART., M.P., Houghton Hall, Fence Houses (PAST PRESIDENT, *Member of Council*) Aug. 21, 1852
196 ELLIOT, W. S., Marlowes House, Hemel Hampstead, Hertfordshire ... Sept. 13, 1873
197 ELLIOTT, W. Tudhoe House, Durham 1854
198 ELSDON, ROBERT, 76, Manor Road, Upper New Cross, London ... Nov. 4, 1876
199 EMBLETON, T. W., The Cedars, Methley, Leeds ... ... Sept. 6, 1855
200 EMBLETON, T. W., Jun., The Cedars, Methley, Leeds ... ... Sept. 2, 1865
201 EMINSON, J. B., Londonderry Offices, Seaham Harbour ... ... Mar. 2, 1872
202 EVERARD, I. B., M.E., 6, Millstone Lane, Leicester ... ... Mar. 6, 1869

203 FARMER, A., So. Durham Fitting Offices, West Hartlepool ... ... Mar. 2, 1872
204 FARRAR, JAMES, Old Foundry, Barnsley ... ... July 2, 1872
205 FAVELL, THOMAS M., 14, Saville Street, North Shields ... ... April 5, 1873
206 FEARN, JOHN WILMOT, Chesterfield ... ... Mar. 6, 1869
207 FENWICK, BARNABAS, Team Colliery, Gateshead ... ... Aug. 2, 1866
208 FENWICK, GEORGE, Banker, Newcastle-on-Tyne ... ... Sept. 2, 1871
209 FENWICK, THOMAS, East Pontop Colliery, by Lintz Green ... ... April 5, 1873
210 FERENS, ROBINSON, Oswald Hall, near Durham ... ... April 7, 1877
211 FIDLER, E., Platt Lane Colliery, Wigan, Lancashire ... ... Sept. 1, 1866
212 FISHER, R. C., The Wern, Ystalyfera, Swansea ... ... July 2, 1872

ELECTED.

213 FLETCHER, GEO., Hamsteels Colliery, near Durham ... ... Aug. 1, 1874
214 FLETCHER, H., Ladyshore Coll., Little Lever, Bolton, Lancashire ... Aug. 3, 1865
215 FLETCHER, JAS., Manager Co-operative Collieries, Wallsend, near Newcastle, New South Wales ... ... Sept. 11, 1875
216 FLETCHER, J., Kelton House, Dumfries ... ... July 2, 1872
217 FLETCHER, W., Waterhead, Ambleside ... ... Feb. 4, 1871
218 FOGGIN, WILLIAM, Pensher Colliery, Fence Houses ... ... Mar. 6, 1875
219 FORREST, J., Assoc. Inst. C.E., Pentrehobin Hall, Mold, Flintshire ... Mar. 5, 1870
220 FORSTER, G. B., M.A., Backworth House, near Newcastle-upon-Tyne (VICE-PRESIDENT) Nov. 5, 1852
221 FORSTER, J. R., Water Co.'s Office, Newcastle-on-Tyne ... ... July 2, 1872
222 FORSTER, J. T., Waldridge Colliery, Chester-le-Street ... ... Aug. 1, 1868
223 FORSTER, RICHARD, 51, Quayside, Newcastle-on-Tyne ... ... Oct. 5, 1872
224 FORSTER, R., South Hetton, Fence Houses ... ... Sept. 5, 1868
225 FOSTER, GEORGE, Osmondthorpe Colliery, near Leeds ... ... Mar. 7, 1874
226 FOTHERGILL, J., King Street, Quay, Newcastle-on-Tyne ... ... Aug. 7, 1862
227 FRANCE, FRANCIS, St. Helen's Colliery Co. Ld., St. Helen's, Lancashire Sept. 1, 1877
228 FRANCE, W., Lofthouse Mines, Saltburn-by-the-Sea ... ... April 6, 1867
229 FRANKS, GEORGE, Victoria Garesfield, Lintz Green ... ... Feb. 6, 1875
230 FRAZIER, PROF. B. W., Lehigh University, Bethlehem, Penns., U.S... Nov. 2, 1872
231 FURNESS, H. D., Close House, Ravensworth, Gateshead-on-Tyne Dec. 2, 1871

232 GALLOWAY, R. L., Ryton-on-Tyne ... ... Dec. 6, 1873
233 GALLOWAY, T. LINDSAY, M.A., 1, St. Nicholas' Buildings, Newcastle-on-Tyne ... ... *(Member of Council)* Sept. 2, 1876
234 GARDNER, WALTER, M.E., The Stone House, Rugeley ... ... Feb. 14, 1874
235 GERRARD, JOHN, Westgate, Wakefield ... ... Mar. 5, 1870
236 GIBSON, JOHN, Ryhope Colliery, near Sunderland ... ... Dec. 4, 1875
237 GILL, HARRY, Consulting Engineer, Newcastle-on-Tyne ... ... May 2, 1874
238 GILLETT, F. C., Midland Road, Derby ... ... July 4, 1861
239 GILMOUR, D., Portland Colliery, Kilmarnock ... ... Feb. 3, 1872
240 GILPIN, EDWIN, 26, Spring Gardens, Halifax, Nova Scotia ... ... April 5, 1873
241 GILROY, G., Ince Hall Colliery, Wigan, Lancashire ... ... Aug. 7, 1856
242 GILROY, S. B., M.E., Powell Duffryn Collieries, Aberdare ... ... Sept. 5, 1868
243 GJERS, JOHN, Southfield Villas, Middlesbro' ... ... June 7, 1873
244 GODDARD, F. R., Accountant, Newcastle-on-Tyne ... ... Nov. 7, 1874
245 GOOCH, G. H., Lintz Colliery, Burnopfield, Gateshead... ... ... Oct. 3, 1856
246 GOODMAN, A., Walker Iron Works, Newcastle-on-Tyne ... ... Sept. 5, 1868
247 GORDON, JAMES N., c/o W. Nicolson, 5, Jeffrey's Square, St. Mary Axe, London, E.C. ... ... Nov. 6, 1875
248 GOTT, WILLIAM L. ... ... Sept. 3, 1864
249 GRACE, E. N., Dhadka, Assensole, Bengal, India ... ... Feb. 1, 1868
250 GRANT, J. H., District Engineer, Beerbhoon, Bengal, India ... ... Sept. 4, 1869
251 GRAY, THOMAS, Underhill, Taibach, South Wales ... ... June 5, 1869
252 GREAVES, J. O., M.E., St. John's, Wakefield ... ... Aug. 7, 1862
253 GREEN, J. T., Abercarn Fach, near Newport, Monmouthshire ... Dec. 3, 1870
254 GREEN, W., Jun., Thornelly House, Lintz Green *(Member of Council)* Feb. 4 1853

ELECTED

255 GREENER, JOHN, General Manager, Vale Coll., Pictou, Nova Scotia ... Feb. 6, 1875
256 GREENER, T., 76, Arlingford Road, Brixton, London, S.W. ... ... Aug. 3, 1865
257 GREENWELL, G. C., Tynemouth ... ... (PRESIDENT) Aug. 21, 1852
258 GREENWELL, G. C., Jun., Poynton, near Stockport ... ... Mar. 6, 1869
259 GREIG, D., Leeds ... ... Aug. 2, 1866
260 GREY, C. G., 55, Parliament Street, London ... ... May 4, 1872
261 GRIEVES, D., Brancepeth Colliery, Willington, County Durham ... Nov. 7, 1874
262 GRIFFITH, N. R., Wrexham 1866
263 GRIMSHAW, E. J., Cowley Hill, St. Helen's, Lancashire ... ... Sept. 5, 1868
264 GRIMSHAW, W. J., Stand Lane Colliery, Radcliffe, Manchester ... Nov. 1, 1873
265 GROUND, H. N., Redheugh Colliery, Gateshead-on-Tyne ... ... July 2, 1872
266 GUINOTTE, LUCIEN, Directeur des Charbonnages de Mariemont et de Bascoup, Mons, Belgium ... ... Sept. 2, 1871

267 HAGGIE, D. H., Wearmouth Patent Rope Works, Sunderland ... Mar. 4, 1876
268 HAGGIE, P., Gateshead 1854
269*HAGUE, ERNEST, Castle Dyke, Sheffield ... ... Mar. 2, 1872
270 HAINES, J. RICHARD, Adderley Green Colliery, near Longton ... Nov. 7, 1874
271 HALES, C., Nerquis Cottage, Nerquis, near Mold, Flintshire 1865
272 HALL, F. W., 1, Eslington Terrace, Jesmond Road, Newcastle-on-Tyne Aug. 7, 1869
273 HALL, GEORGE, South Garesfield Colliery, Lintz Green ... ... Mar. 6, 1875
274 HALL, M., Lofthouse Station Collieries, near Wakefield ... ... Sept. 5, 1868
275 HALL, M. S., M.E., Westerton, near Bishop Auckland ... ... Feb. 14, 1874
276 HALL, W., Spring Hill Mines, Cumberland County, Nova Scotia ... Sept. 13, 1873
277 HALL, WM., Thornley Colliery, County Durham ... ... Dec. 4, 1875
278 HALL, WILLIAM F., Haswell Colliery, Fence Houses ... ... May 13, 1858
279 HANN, EDMUND, Glanmoor Villa, Uplands, Swansea ... ... Sept. 5, 1868
280 HARBOTTLE, W. H., Orrell Colliery, near Wigan ... ... Dec. 4, 1875
281 HARDY, JOS., Preston Colliery, North Shields ... ... June 2, 1877
282 HARGREAVES, WILLIAM, Rothwell Haigh, Leeds ... ... Sept. 5, 1868
283 HARLE, RICHARD, Browney Colliery, Durham ... ... April 7, 1877
284 HARLE, WILLIAM, Pagebank Colliery, near Durham ... ... Oct. 7, 1876
285 HARRISON, R., Eastwood, near Nottingham 1861
286 HARRISON, T., Great Western Colliery, Pontypridd, Glamorganshire Aug. 2, 1873
287 HARRISON, T. E., C.E., Central Station, Newcastle-on-Tyne ... ... May 6, 1853
288 HARRISON, W. B., Brownhills Collieries, near Walsall ... ... April 6, 1867
289 HASWELL, G. H., 11, South Preston Terrace, North Shields ... ... Mar. 2, 1872
290 HAWTHORN, T., 98, Rye Hill, Newcastle-on-Tyne *(Mem. of Council)* Dec. 6, 1866
291 HAY, J., Jun., Widdrington Colliery, Acklington ... ... Sept. 4, 1869
292 HECKELS, MATTHEW, Castle Eden Colliery, Co. Durham ... ... April 11, 1874
293 HECKELS, W. J. ... ... May 2, 1868
294 HEDLEY, EDW., 2, Church Street, London Road, Derby ... ... Dec. 2, 1858
295 HEDLEY, J. J., Consett Collieries, Leadgate, County Durham ... April 6, 1872
296 HEDLEY, J. L., 3, Elm Vale, Fairfield, Liverpool ... ... Feb. 5, 1870
297 HEDLEY, T. F., Valuer, Sunderland ... ... Mar. 4, 1871
298 HEDLEY, W. H., Consett Collieries, Medomsley, Newcastle-on-Tyne *(Member of Council)* 1864

ELECTED.

299 HENDERSON, H., Pelton Colliery, Chester-le-Street ... ... Feb. 14, 1874
300 HENDERSON, JOHN, Leazes House, Durham ... ... Mar. 5, 1870
301 HEPPELL, T., Leafield House, Birtley, Fence Houses *(Mem. of Council)* Aug. 6, 1863
302 HEPPELL, W., Brancepeth Colliery, Willington, County Durham ... Mar. 2, 1872
303 HERDMAN, J., Park Crescent, Bridgend, Glamorganshire ... ... Oct. 4, 1860
304 HESLOP, C., Lingdale Mines, *via* Guisborough ... ... Feb. 1, 1868
305 HESLOP, GRAINGER, Whitwell Colliery, Sunderland ... ... Oct. 5, 1872
306 HESLOP, J., Hucknall Torkard Colliery, near Nottingham ... ... Feb. 6, 1864
307 HETHERINGTON, D., Coxlodge Colliery, Newcastle-on-Tyne 1859
308* HEWITT, G. C., Coal Pit Heath Colliery, near Bristol ... ... June 3, 1871
309 HEWLETT, A., Haigh Colliery, Wigan, Lancashire ... ... Mar. 7, 1861
310 HICK, G. W., 14, Blenheim Terrace, Leeds ... ... May 4, 1872
311 HIGSON, JACOB, 94, Cross Street, Manchester 1861
312 HIGSON, P., Crown Chambers, 18, Booth Street, Manchester ... ... Aug. 3, 1865
313 HILL, LESLIE C., Bartholomew House, London, E C. ... ... Nov. 6, 1875
314 HILTON, J., Standish and Shevington Collieries, near Wigan ... Dec. 7, 1867
315 HILTON, T. W., Wigan Coal and Iron Co., Limited, Wigan ... ... Aug. 3, 1865
316 HINDMARSH, THOMAS, Cowpen Lodge, Blyth, Northumberland ... Sept. 2, 1876
317 HODGSON, J. W., Dipton Colliery, *via* Lintz Green Station ... ... Feb. 5, 1870
318 HOLDING, W., Brinsop Hall Coal Co., Wigan ... ... Mar. 3, 1877
319 HOLLIDAY, MARTIN, M.E., Peases' West Collieries, Crook ... ... May 1, 1875
320 HOLMES, C., Grange Hill, near Bishop Auckland ... ... April 11, 1874
321 HOMER, CHARLES J., Caverswall Castle, Stoke-on-Trent ... ... Aug. 3, 1865
322 HOOD, A., 6, Bute Crescent, Cardiff ... ... April 18, 1861
323 HOPE, GEORGE, Newbottle Colliery, Fence Houses ... ... Feb. 3, 1877
324 HORNSBY, H., Whitworth Terrace, *via* Spennymoor, Co. Durham ... Aug. 1, 1874
325 HORSLEY, W., Whitehill Point, Percy Main ... ... Mar. 5, 1857
326 HOSKOLD, H. D., C. and M.E., F.R.G.S., F.G.S., M. Soc. A., &c. ... April 1, 1871
327 HOWARD, W. F., 13, Cavendish Street, Chesterfield ... ... Aug. 1, 1861
328 HUDSON, JAMES, Albion Mines, Pictou, Nova Scotia 1862
329 HUGHES, H. E., Old Durham Colliery, Durham ... ... Nov. 6, 1869
330 HUMBLE, JOHN, West Pelton, Chester-le-Street ... ... Mar. 4, 1871
331 HUMBLE, JOS., Staveley Works, near Chesterfield ... ... June 2, 1866
332 HUNTER, J., Jun., Silkstone and Worsbro' Park Colls., nr. Barnsley ... Mar. 6, 1869
333 HUNTER, W., Monk Bretton Colliery, near Barnsley ... ... Oct. 3, 1861
334 HUNTER, WM., 34, Grey Street, Newcastle ... ... Aug. 21, 1852
335 HUNTER, W. S., Moor Lodge, Newcastle-upon-Tyne ... ... Feb. 1, 1868
336 HUNTING, CHARLES, Fence Houses ... ... Dec. 6, 1866
337 HURST, T. G., F.G.S., Lauder Grange, Corbridge-on-Tyne ... Aug. 21, 1852

338 JACKSON, C. G., Wigan Coal and Iron Co., Limited, Wigan ... ... June 4, 1870
339 JACKSON, W., Cannock Chase Collieries, Walsall ... ... Feb. 14, 1874
340 JACKSON, W. G., Hazel Farm, Methley, near Leeds ... ... June 7, 1873
341 JARRATT, J., Broomside Colliery Office, Durham ... ... Nov. 2, 1867
342 JEFFCOCK, T. W., 18, Bank Street, Sheffield ... ... Sept. 4, 1869
343 JENKINS, W., M.E., Ocean S.C. Colls., Ystrad, nr. Pontypridd, So. Wales Dec. 6, 1862
344 JENKINS, WM., Consett Iron Works, Consett, Durham ... ... May 2, 1874

ELECTED.

345 JOHNASSON, J., Leadenhall Street, London, E.C. ... ... July 2, 1872
346 JOHNSON, HENRY, Dudley, Worcestershire ... ... Aug. 7, 1869
347 JOHNSON, JOHN, M. Inst. C.E., F.G.S., 21, Victoria Square, Newcastle Aug. 21, 1852
348 JOHNSON, J., Witley Colliery Co. Ld., Halesowen, nr. Birmingham Mar. 7, 1874
349 JOHNSON, R. S., Sherburn Hall, Durham ... ... Aug. 21, 1852
350 JOHNSTON, T., Deanmoor Colliery Co., by Cockermouth ... ... April 6, 1872
351 JOICEY, JOHN, Newton Hall, Stocksfield-on-Tyne ... ... Sept. 3, 1852
352 JOICEY, J. G., Forth Banks West Factory, Newcastle-on-Tyne ... April 10, 1869
353 JOICEY, W. J., Tanfield Lea Colliery, Burnopfield ... ... Mar. 6, 1869
354 JORDAN, ROBERT, Ebbw Vale, South Wales ... ... Nov. 7, 1874
355 JOSEPH, D. DAVIS, Ty Draw, Pontypridd, South Wales ... ... April 6, 1872
356 JOSEPH, T., Ty Draw, near Pontypridd, South Wales ... ... April 6, 1872

357 KASALOUSKY, JOSEF ... ... Aug. 1, 1874
358 KELSEY, W., 41, Fawcett Street, Sunderland ... ... Mar. 7, 1874
359 KENDALL, JOHN D., Roper Street, Whitehaven ... ... Oct. 3, 1874
360 KENNEDY, MYLES, M.E., Hill Foot, Ulverstone ... ... June 6, 1868
361 KIMPTON, J. G., 40, St. Mary's Gate, Derby ... ... Oct. 5, 1872
362 KIRKBY, J. W., Ashgrove, Windygates, Fife ... ... Feb. 1, 1873
363 KIRKWOOD, WILLIAM, Larkhall Colliery, Hamilton ... ... Aug. 7, 1869
364 KIRSOPP, JOHN, Team Colliery, Gateshead ... ... April 5, 1873
365 KNOWLES, A., High Bank, Pendlebury, Manchester ... ... Dec. 5, 1856
366 KNOWLES, JOHN, Westwood, Pendlebury, Manchester ... ... Dec. 5, 1856
367 KNOWLES, THOMAS, Ince Hall, Wigan ... ... Aug. 1, 1861
368 KYRKE, R. H. V., Westminster Chambers, Wrexham ... ... Feb. 5, 1870

369 LACKLAND, J. J., Albion Street, Hanley, Staffordshire ... ... Mar. 7, 1874
370 LAIDLER, W. J. ... ... Mar. 4, 1876
371 LAMB, R., Cleator Moor Colliery, near Whitehaven ... ... Sept. 2, 1865
372 LAMB, R. O., Gibside, Lintz Green, Newcastle-on-Tyne ... ... Aug. 2, 1866
373 LAMB, RICHARD W., Coal Owner, Newcastle-on-Tyne... ... ... Nov. 2, 1872
374 LAMBERT, M. W., 9, Queen Street, Newcastle-on-Tyne ... ... July 2, 1872
375 LANCASTER, JOHN, Bilton Grange, Rugby ... ... July 4, 1861
376 LANCASTER, J., Jun., Anfield House, Willes Road, Leamington ... Mar. 2, 1865
377 LANCASTER, S., Nantyglo & Blaina Steam Coal Collieries, Blaina, Mon. Aug. 3, 1865
378 LANDALE, A., Lochgelly Iron Works, Fifeshire, N.B. ... ... Dec. 2, 1858
379*LAPORTE, HENRY, M.E., 80, Rue Royale, Brussels ... ... May 5, 1877
380 LAVERICK, J., 3, Villette Mount, Toward Road, Sunderland ... ... July 2, 1872
381 LAVERICK, ROBT., West Rainton, Fence Houses ... ... Sept. 2, 1876
382 LAWRENCE, HENRY, Grange Iron Works, Durham ... ... Aug. 1, 1868
383 LAWS, H., Grainger Street West, Newcastle-on-Tyne ... ... Feb. 6, 1869
384 LAWS, JOHN, Blyth, Northumberland 1854
385 LAWSON, Rev. E., Longhirst Hall, Morpeth ... ... Dec. 3, 1870
386 LAYCOCK, JOSEPH, Low Gosforth, Northumberland ... ... Sept. 4, 1869
387 LEATHER, J. T., Middleton Hall, Belford, Northumberland ... ... Aug. 6, 1870
388 LEBOUR, G. A., M.A., F.G.S., College of Physical Science, Newcastle Feb. 1, 1873
389 LEE, GEORGE, Loftus-in-Cleveland ... ... June 4, 1870

ELECTED.

390 LESLIE, ANDREW, Hebburn, Gateshead-on-Tyne ... ... Sept. 7, 1867
391 LEVER, ELLIS, Bowdon, Cheshire 1861
392 LEWIS, HENRY, Annesley Colliery, near Nottingham ... ... Aug. 2, 1866
393 LEWIS, W. H., 3, Bute Crescent, Cardiff ... ... Aug. 4, 1877
394 LEWIS, WILLIAM THOMAS, Mardy, Aberdare 1864
395 LIDDELL, G. H., Somerset House, Whitehaven ... ... Sept. 4, 1869
396 LIDDELL, M., Prudhoe Hall, Prudhoe-on-Tyne ... ... Oct. 1, 1852
397 LINDOP, JAMES, Bloxwich, Walsall, Staffordshire ... ... Aug. 1, 1861
398 LINSLEY, R., Cramlington Colliery, Northumberland ... ... July 2, 1872
399 LINSLEY, S. W., Whitburn Colliery, Sunderland ... ... Sept. 4, 1869
400 LISHMAN, T., Jun., Hetton Colliery, Fence Houses ... ... Nov. 5, 1870
401 LISHMAN, WM., Witton-le-Wear 1857
402 LISHMAN, WM., Bunker Hill, Fence Houses *(Member of Council)* Mar. 7, 1861
403 LIVESEY, C., Bredbury Colliery, Bredbury, Stockport ... ... Aug. 3, 1865
404 LIVESEY, T., Jun., Hatherlow House, Romiley, near Stockport ... Nov. 7, 1874
405 LLEWELLIN, D., Glanwern Offices, Pontypool, Monmouthshire ... Aug. 4, 1864
406 LLEWELYN, L., Risca Collieries, near Newport, Mon. ... ... May 4, 1872
407 LOGAN, WILLIAM, Langley Park Colliery, Durham ... ... Sept. 7, 1867
408 LONGBOTHAM, J., Norley Collieries, near Wigan ... ... May 2, 1868
409 LONGRIDGE, J. A., 3, Westminster Chambers, Victoria St., London, S.W. Aug. 21, 1852
410 LOW, W., Vron Colliery, Wrexham, Denbighshire ... ... Sept. 6, 1855
411 LUPTON, A., F.G.S., Crossgates, near Leeds ... ... Nov. 6, 1869

412 MACKENZIE, J., Ashgrove Villa, Ibroxholm, Paisley Road, Glasgow ... Mar. 5, 1870
413 MADDISON, HENRY, The Lindens, Darlington ... ... Nov. 6, 1875
414 MALING, C. T., Ford Pottery, Newcastle-on-Tyne ... ... Oct. 5, 1872
415 MAMMATT, J. E., C.E., St. Andrew's Chambers, Leeds 1864
416 MARLEY, JOHN, Mining Offices, Darlington ... (VICE-PRESIDENT) Aug. 21, 1852
417 MARLEY, J. W., Mining Offices, Darlington ... ... Aug. 1, 1868
418 MARSHALL, F. C., Messrs. Hawthorn & Co., Newcastle ... ... Aug. 2, 1866
419 MARSHALL, J. 1864
420 MARSTON, W. B., Leeswood Vale Oil Works, Mold ... ... Oct. 3, 1868
421 MARTEN, E. B., C.E., Pedmore, near Stourbridge ... ... July 2, 1872
422 MARTIN, R. F., Mount Sorrel, Loughborough ... ... April 11, 1874
423 MATTHEWS, R. F., Seaton Carew, West Hartlepool ... ... Mar. 5, 1857
424 MAUGHAN, J. A., Nerbudda Coal and Iron Co. Limited, Garrawarra, Central Provinces, India ... ... Nov. 7, 1863
425 MAUGHAN, J. D., Hebburn Colliery, near Newcastle-on-Tyne ... Nov. 4, 1876
426 MAY, GEORGE, Harton Colliery Offices, Tyne Docks, South Shields *(Member of Council)* Mar. 6, 1862
427 MCCREATH, J., 95, Bath Street, Glasgow ... ... Mar. 5, 1870
428 MCCULLOCH, DAVID, Beech Grove, Kilmarnock, N.B. ... ... Dec. 4, 1875
429 MCCULLOCH, H. J., Moat House, Wood Green, London, N. ... ... Oct. 1, 1863
430 MCCULLOCH, W., 178, Gresham House, Old Broad Street, London, E.C. Nov. 7, 1874
431 MCGHIE, T., Cannock, Staffordshire ... ... Oct. 1, 1857
432 MCMURTRIE, J., Radstock Colliery, Bath ... ... Nov. 7, 1863
433 MEADOWS, J. M., 11, Eustace Street, Dublin ... ... Dec. 4, 1875

ELECTED.

434 MEIK, THOMAS, C.E., 6, York Place, Edinburgh ... ... June 4, 1870
435 MERIVALE, J. H., Nedderton, R.S.O., Northumberland ... ... May 5, 1877
436 MILLER, ROBERT, Strafford Collieries, near Barnsley ... ... Mar. 2, 1865
437 MILLS, M. H., Duckmanton Lodge, Chesterfield ... ... Feb. 4, 1871
438 MITCHELL, CHAS., Jesmond, Newcastle-on-Tyne *(Member of Council)* April 11, 1874
439 MITCHELL, JOSEPH, Jun., Worsbro' Dale, near Barnsley ... ... Feb, 14, 1874
440 MITCHINSON, R., Jun., Pontop Coll., Lintz Green Station, Co. Durham Feb. 4, 1865
441 MOFFATT, T., Montreal Iron Ore Works, Whitehaven ... ... Sept. 4, 1869
442 MONKHOUSE, JOS., Yeat House, Frizington, Whitehaven ... ... June 4, 1863
443 MOOR, T., Cambois Colliery, Blyth ... ... Oct. 3, 1868
444 MOOR, W., Engineer, Hetton Colliery, Fence Houses ... ... Oct. 3, 1874
445 MOOR, WM., Jun., Hetton Colliery, Fence Houses ... ... July 2, 1872
446 MOORE, R. W., Colliery Office, Whitehaven ... ... Nov. 5, 1870
447 MOORE, T. H., Smeaton Park, Inveresk, Edinburgh ... ... Feb. 2, 1867
448 MORISON, D. P., 21, Collingwood St., Newcastle *(Member of Council)* 1861
449 MORRELL, JOHN, Darlington ... ... Oct. 7, 1876
450 MORRIS, W., Waldridge Colliery, Chester-le-Street, Fence Houses ... 1858
451*MORTON, H. J., 4, Royal Crescent, Scarborough 1861
452 MORTON, H. T., Lambton, Fence Houses ... ... Aug. 21, 1852
453 MOSES, WM., Lumley Colliery, Fence Houses ... ... Mar. 2, 1872
454 MUCKLE, JOHN, Monk Bretton, Barnsley ... ... Mar. 7, 1861
455 MULCASTER, W., Jun., M.E., Croft House, Aspatria, near Carlisle ... Dec. 3, 1870
456 MULVANY, W. T., Pempelfort, Dusseldorf-on-the-Rhine ... ... Dec. 3, 1857
457 MUNDLE, ARTHUR, Tyne View House, Blaydon-on-Tyne ... ... June 5, 1875
458 MUNDLE, W., Redesdale Mines, Bellingham ... ... Aug. 2, 1873

459 NANSON, J. ... ... Dec. 4, 1869
460 NASSE, HERR BERGASSESSOR, Louisenthal, Saarbrucken, Prussia ... Sept. 4, 1869
461 NAYLOR, J. T., 10, West Clayton Street, Newcastle-on-Tyne ... ... Dec. 6, 1866
462 NELSON, J., C.E., Marine and Stationary Engine Works, Gateshead *(Member of Council)* Oct. 4. 1866
463 NEVIN, JOHN, Mirfield, Yorkshire ... ... May 2, 1868
464 NEWALL, R. S., Ferndene, Gateshead ... *(Member of Council)* May 2, 1863
465 NICHOLSON, E., jun., Beamish Colliery, Chester-le-Street ... ... Aug. 7, 1869
466 NICHOLSON, J. W., 36, Crown St., Elswick Road, Newcastle-on-Tyne Oct. 11, 1873
467 NICHOLSON, MARSHALL, Middleton Hall, Leeds ... ... Nov. 7, 1863
468 NOBLE, CAPTAIN, Jesmond, Newcastle-upon-Tyne ... ... Feb. 3, 1866
469 NORTH, F. W., F.G.S., Rowley Hall Colliery, Dudley, Staffordshire ... Oct. 6, 1864
470 NUTTALL, THOMAS, Broad Street, Bury, Lancashire ... ... Sept. 11, 1875

471 OGDEN, JOHN M., Solicitor, Sunderland ... ... Mar. 5, 1857
472 OGILVIE, A. GRAEME, 4, Great George Street, Westminster, London Mar. 3, 1877
473 OLIVER, ROBERT, Charlaw Colliery, near Durham ... ... Nov. 6, 1875
474 OWEN, J. H., 18, Prudhoe Terrace, Tynemouth ... ... Aug. 4, 1877

475 PACEY, T., Bishop Auckland ... ... April 10, 1869
476 PAGE, WILLIAM, Merryweather & Co., York St., Lambeth, London, S.E. Mar. 6, 1875

ELECTED.

477 PALMER, A. S., Wardley Hall, near Newcastle-on-Tyne ... ... July 2, 1872
478 PALMER, C. M., M.P., Quay, Newcastle-upon-Tyne ... ... Nov. 5, 1852
479 PAMELY, C., Radstock Coal Works, near Bath ... ... Sept. 5, 1868
480 PANTON, F. S., Silksworth Colliery, Sunderland ... ... Oct. 5, 1867
481 PARKIN, C., Deer Park Mines, Newlyn East, Grampound Rd., Cornwall June 5, 1875
482 PARKIN, JOHN, Westbourne Grove, Redcar, Yorkshire... ... ... April 11, 1874
483 PARRINGTON, M. W., Wearmouth Colliery, Sunderland ... ... Dec. 1, 1864
484 PARTON, T., F.G.S., Ash Cottage, Birmingham Road, West Bromwich Oct. 2, 1869
485 PATTISON, JOHN, Engineer, Naples ... ... Nov. 7, 1874
486 PEACE, M. W., Wigan, Lancashire ... ... July 2, 1872
487 PEACOCK, DAVID, Westbromwich ... ... Aug. 7, 1869
488 PEARCE, F. H., Bowling Iron Works, Bradford ... ... Oct. 1, 1857
489 PEARSON, J. E., Golborne Park, near Newton-le-Willows ... ... Feb. 3, 1872
490 PEASE, J. W., M.P., Hutton Hall, Guisbro', Yorkshire ... ... Mar. 5, 1857
491 PEEL, JOHN, Wharncliffe and Silkstone Coll., Wortley, near Sheffield Nov. 1, 1860
492 PEEL, JOHN, Horsley Colliery, Wylam-on-Tyne ... ... Mar. 3, 1877
493 PEILE, WILLIAM, Rosemount, Roath, Cardiff ... ... Oct. 1, 1863
494 PENMAN, J. H., 2, Clarence Buildings, Booth Street, Manchester ... Mar. 7, 1874
495 PERROT, S. W., 39, Kronprinzen Strasse, Dusseldorf ... ... June 2, 1866
496 PHILIPSON, H., 8, Queen Street, Newcastle-upon-Tyne ... ... Oct. 7, 1871
497 PICKERSGILL, T. Waterloo Main Colliery, near Leeds ... ... June 5, 1869
498 PICKUP, P. W., Dunkenhalgh Collieries, Accrington, Lancashire ... Feb. 6, 1875
499 PINCHING, ARCHD. E., The Terrace, Gravesend ... ... May 5, 1877
500 POTTER, ADDISON, Heaton Hall, Newcastle-on-Tyne ... ... Mar. 6, 1869
501 POTTER, A. M., Shiremoor Coll., Northumberland *(Member of Council)* Feb. 3, 1872
502 POTTER, C. J., Heaton Hall, Newcastle-on-Tyne ... ... Oct. 3, 1874
503* POTTER, W. A., Cramlington House, Northumberland 1853
504 PRICE, JOHN, Messrs. Palmer Brothers & Co., Jarrow-on-Tyne ... Mar. 3, 1877
505 PRICE, J. R., Standish, near Wigan ... ... Aug. 7, 1869
506 PRIESTMAN, JON., Coal Owner, Newcastle-on-Tyne ... ... Sept. 2, 1871
507 PRINGLE, EDWARD, Choppington Colliery, Northumberland ... ... Aug. 4, 1877

508 RAILSTON, C. A., Framlington Place, Newcastle-on-Tyne ... ... Feb. 3, 1877
509 RAMSAY, J. A., Chesterton, near Newcastle-under-Lyne, Staffordshire Mar. 6, 1869
510 RAMSAY, J. T., Walbottle Hall, nr. Blaydon-on-Tyne *(Mem. of Council)* Aug. 3, 1853
511 RAMSAY, T. D. ... ... Mar. 1, 1866
512 RAMSAY, WM., Tursdale Colliery, County Durham ... ... Sept. 11, 1875
513 REED, ROBERT, Felling Colliery, Gateshead ... ... Dec. 3, 1863
514 REES, DANIEL, Glandare, Aberdare 1862
515 REFEEN, WM., Teplitz, Bohemia ... ... Oct. 5, 1872
516 REID, ANDREW, Newcastle-on-Tyne ... ... April 2, 1870
517 REYNOLDS, J. J., M.E., Leigh Road, Atherton, near Manchester ... April 3, 1875
518 RICHARDS, CHARLES ... ... Mar. 3, 1877
519 RICHARDS, E. W., Messrs. Bolckow, Vaughan, & Co., Middlesbro' ... Aug. 5, 1876
520 RICHARDS, G. C., M.E., Woodhouse, near Sheffield ... ... June 5, 1875
521 RICHARDSON, H., Backworth Colliery, Newcastle-on-Tyne ... ... Mar. 2, 1865
522 RICHARDSON, J. W., Iron Shipbuilder, Newcastle-on-Tyne ... ... Sept. 3, 1870

ELECTED.

523 RIDLEY, G., Trinity Chambers, Newcastle-on-Tyne ... ... Feb. 4, 1865
524 RIDLEY, J. H., R. & W. Hawthorn's, Newcastle-on-Tyne ... ... April 6, 1872
525 RIDYARD, JOHN, Walkden, near Bolton-le-Moors, Lancashire ... Nov. 7, 1874
526 RIGBY, JOHN, Ash Villa, Alsager, Stoke-upon-Trent ... ... Feb. 5, 1876
527 RITSON, U. A., 6, Queen Street, Newcastle-on-Tyne ... ... Oct. 7, 1871
528 RITSON, W. A., Shilbottle Colliery, near Alnwick ... ... April 2, 1870
529 ROBERTSON, W., M.E., 123, St. Vincent Street, Glasgow ... ... Mar. 5, 1870
530 ROBINSON, G. C., Brereton and Hayes Colls., Rugeley, Staffordshire... Nov. 5, 1870
531 ROBINSON, H., C.E., 7, Westminster Chambers, London ... ... Sept. 3, 1870
532 ROBINSON, JOHN, Hebburn Colliery, near Newcastle-on-Tyne ... Nov. 4, 1876
533 ROBINSON, R., Howlish Hall, near Bishop Auckland ... ... Feb. 1, 1868
534 ROBSON, E., Middlesbro'-on-Tees... ... ... April 2, 1870
535 ROBSON, J. S., Butterknowle Colliery, *via* Darlington... 1853
536 ROBSON, J. T., Cambuslang, Glasgow ... ... Sept. 4, 1869
537 ROBSON, M. ... ... May 4, 1872
538 ROBSON, THOMAS, Lumley Colliery, Fence Houses ... ... Oct. 4, 1860
539 ROGERSON, John, Croxdale Hall, Durham ... ... Mar. 6, 1869
540 ROSCAMP, J., Rosedale Lodge, near Pickering, Yorkshire ... ... Feb. 2, 1867
541 ROSEBY, JOHN, Haverholme House, Brigg, Lincolnshire ... ... Nov. 2, 1872
542 ROSS, A., Shipcote Colliery, Gateshead ... ... Oct. 1, 1857
543 ROSS, J. A. G., Consulting Engineer, Bath Lane, Newcastle ... ... July 2, 1872
544 ROSSER, W., Mineral Surveyor, Llanelly, Carmarthenshire 1856
545 ROTHWELL, R. P., 27, Park Place, New York ... ... Mar. 5, 1870
546 ROUTLEDGE, Jos., Ryhope Colliery, Sunderland ... ... Sept. 11, 1875
547 ROUTLEDGE, J. L., Ryhope Colliery, Sunderland ... ... Oct. 7, 1876
548 ROUTLEDGE, WM., Sydney, Cape Breton ... ... Aug. 6, 1857
549 ROWLEY, J. C., Shagpoint Colliery, Otago, New Zealand ... ... Dec. 4, 1875
550 RUTHERFORD, J., Halifax, Nova Scotia 1866
551 RUTHERFORD, W., Marden House, Whitley, Newcastle-on-Tyne ... Oct. 3, 1874
552 RUTTER, THOS., Blaydon Main Colliery, Blaydon-on-Tyne ... ... May 1, 1875
553 RYDER, W. J. H., Forth Street Brass Works, Newcastle-on-Tyne ... Nov. 4, 1876

554 SAINT, GEORGE, Vauxhall Collieries, Ruabon, North Wales ... ... April 11, 1874
555 SCARTH, W. T., Raby Castle, Darlington ... ... April 4, 1868
556 SCOTT, ANDREW, Broomhill Colliery, Acklington ... ... Dec. 7, 1867
557 SCOTT, C. F., Cooper's Wentworth Colliery, Stainboro', near Barnsley April 11, 1874
558 SCOULAR, G., Parkside, Frizington, Cumberland ... ... July 2, 1872
559 SEDDON, J. F., Great Harwood Collieries, near Accrington ... ... June 1, 1867
560 SEDDON, W., Dunkirk Collieries, Dukinfield ... ... Oct. 5, 1865
561 SHALLIS, F. W., M. and J. Pritchard, 9, Gracechurch Street, London April 6, 1872
562 SHAW, JOHN, Neptune Engine Works, Low Walker, Newcastle ... Nov. 6, 1875
563 SHAW, W., Jun., Wolsingham, *via* Darlington... ... ... June 3, 1871
564 SHIEL, JOHN, Framwellgate Colliery, County Durham ... ... May 6, 1871
565 SHONE, ISAAC, Pentrefelin House, Wrexham 1858
566 SHORTREDE, T., Park House, Winstanley, Wigan ... ... April 3, 1856
567 SHUTE, C A., Westoe, South Shields ... ... April 11, 1874
568 SIMPSON, J., Heworth Colliery, near Gateshead-on-Tyne ... ... Dec. 6, 1866

ELECTED.

569 SIMPSON, JOS., Catchgate, near Annfield Plain ... ... Mar. 3, 1873
570 SIMPSON, J. B., Hedgefield House, Blaydon-on-Tyne (VICE-PRESIDENT) Oct. 4, 1860
571 SIMPSON, J. C., Bankhead Colliery, Muirkirk ... ... April 7, 1877
572 SIMPSON, R., Moor House, Ryton-on-Tyne ... ... Aug. 21, 1852
573 SIMPSON, ROBT., Drummond Colliery, Westville, Pictou, N.S. ... Dec. 4, 1875
574 SINCLAIR, JAMES, 48, Blackfriars Street, Manchester ... ... May 6, 1876
575 SLINN, T., 2, Choppington Street, Westmorland Road, Newcastle ... July 2, 1872
576 SMALL, G., Duffield Road, Derby ... ... June 4, 1870
577 SMITH, E. J., 16, Whitehall Place, Westminster, London ... ... Oct. 7, 1858
578 SMITH, G. F., Grovehurst, Tunbridge Wells ... ... Aug. 5, 1853
579 SMITH, J., Bickershaw Colliery, Leigh, near Manchester ... ... Mar. 7, 1874
580* SMITH, R. CLIFFORD, Parkfield, Swinton, Manchester ... ... Dec. 5, 1874
581 SMITH, T., Sen., M.E., Cinderford Villas, nr. Newnham, Gloucester... May, 5, 1877
582 SMITH, T. E., M.P., Gosforth House, Dudley, Northumberland ... Feb. 5, 1870
583 SMITH, T. E., Phœnix Foundry, Newgate Street, Newcastle-on-Tyne Dec. 5, 1874
584 SNOWDON, T., Jun., West Bitchburn Coll., nr. Towlaw, *via* Darlington Sept. 4, 1869
585 SOPWITH, A., Cannock Chase Collieries, near Walsall ... ... Aug. 1, 1868
586 SOPWITH, T., Jun., 48, Northumberland Street, Newcastle ... ... Nov. 2, 1867
587 SOPWITH, THOS., 6, Great George St., Westminster, London, S.W. ... Mar. 3, 1877
588 SOUTHALL, F., Park Hall Colliery, Cheadle, Stoke-upon-Trent ... Feb. 5, 1876
589 SOUTHERN, R., Burleigh House, The Parade, Tredegarville, Cardiff ... Aug. 3, 1865
590 SOUTHWORTH, THOS., Hindley Green Collieries, near Wigan ... ... May 2, 1874
591 SPARK, H. K., Startforth House, Barnard Castle 1856
592 SPENCE, G., 31, Brunton Place, Warwick Road, Carlisle ... ... June 7, 1873
593 SPENCE, JAMES, Clifton and Millgramfitz Collieries, Workington ... Nov. 7, 1874
594 SPENCER, JOHN, Westgate Road, Newcastle-on-Tyne ... ... Sept. 4, 1869
595 SPENCER, JOHN P., Borough Surveyor, Tynemouth ... ... Dec. 5, 1874
596 SPENCER, M., Newburn, near Newcastle-on-Tyne ... ... Sept. 4, 1869
597 SPENCER, T., Ryton, Newcastle-on-Tyne ... ... Dec. 6, 1866
598 SPENCER, W., Cross House Chambers, Westgate Road, Newcastle ... Aug. 21, 1852
599 STAINTON, MATTHEW, Ironfounder, South Shields ... ... May 6, 1876
600 STEAVENSON, A. L., Durham ... ... (VICE-PRESIDENT) Dec. 6, 1855
601 STEAVENSON, D. F., B.A., LL.B., Barrister-at-Law, Cross House, Westgate Road, Newcastle-on-Tyne ... ... April 1, 1871
602 STEELE, CHAS., Bolton Colliery, Mealsgate, Cumberland ... ... June 7, 1873
603 STEELE, CHARLES R., 28, Wood Street, Maryport ... ... Mar. 3, 1864
604 STEPHENSON, G. R., 9, Victoria Chambers, Westminster, London, S.W. Oct. 4, 1860
605 STEPHENSON, W. H., Elswick House, Newcastle-on-Tyne ... ... Mar. 7, 1867
606 STEVENSON, R., Crewe Coal & Iron Co. Ld, Newcastle-under-Lyme ... Feb. 5, 1876
607 STOBART, H. S., Witton-le-Wear, Darlington ... ... Feb. 2, 1854
608 STOBART, W., Wearmouth Colliery, Sunderland ... ... July 2, 1872
609 STOKOE, JOSEPH, Houghton-le-Spring, Fence Houses ... ... April 11, 1874
610 STOREY, THOS. E., Clough Hall Iron Works, Kidsgrove, Staffordshire Feb. 5, 1876
611 STRAKER, JOHN, Stagshaw House, Corbridge-on-Tyne ... ... May 2, 1867
612 STRAKER, J. H., Willington House, Co. Durham ... ... Oct. 3, 1874
613 STRATTON, T. H. M., Seaham Colliery, Sunderland ... ... Dec. 3, 1870
614 SWALLOW, J., Pontop Hall, Lintz Green ... ... May 2, 1874

ELECTED

615 SWALLOW, R. T., Springwell, Gateshead 1862
616 SWAN, H. F., Shipbuilder, Newcastle-on-Tyne ... ... Sept. 2, 1871
617 SWAN, J. G., Upsall Hall, near Middlesbro' ... ... Sept. 2, 1871
618 SWANN, C. G., Secretary, General Mining Association Limited, 6, New Broad Street, London ... ... Aug. 7. 1875

619 TATE, SIMON, Kimblesworth Colliery, Co. Durham ... ... Sept. 11, 1875
620 TAYLOR, GEORGE, Brotton Mines, Saltburn-by-the-Sea ... ... June 5, 1875
621 TAYLOR, HUGH, King Street, Quay, Newcastle-on-Tyne ... ... Sept. 5, 1856
622 TAYLOR, JOHN B., Wollescote House, near Stourbridge ... ... May 3, 1873
623 TAYLOR, T., King Street, Quay, Newcastle-on-Tyne ... ... July 2, 1872
624 TAYLOR-SMITH, THOMAS, Urpeth Hall, Chester-le-Street ... ... Aug. 2, 1866
625 THOMAS, A., Bilson House, near Newnham, Gloucestershire ... ... Mar. 2, 1872
626 THOMPSON, JAMES, Hurworth, Darlington ... ... June 2, 1866
627 THOMPSON, JOHN, Boughton Hall, Chester ... ... Sept. 2, 1865
628 THOMPSON, J., Hilton House, Blackrod, near Chorley... ... ... April 6, 1867
629 THOMPSON, R., Jun., Rodridge House, Wingate, Co. Durham ... Sept. 7, 1867
630 THOMPSON, T. C., Milton Hall, Carlisle ... ... May 4, 1854
631 THOMSON, JOHN, South Skelton Mines, *via* Guisbro' ... ... April 7, 1877
632 THOMSON, JOS. F., Manvers Main Colliery, Rotherham ... ... Feb. 6, 1875
633 THORPE, R. S., 17, Picton Place, Newcastle-on-Tyne ... ... Sept. 5, 1868
634 THUBRON, N., Broadoak Colliery, Longhor, near Swansea ... ... Oct. 3, 1874
635 TINN, J., C.E., Ashton Iron Rolling Mills, Bower Ashton, Bristol ... Sept. 7, 1867
636 TONE, J. F., C.E. ... ... Feb. 7, 1856
637 TYLDEN-WRIGHT, C., Shirecaks Colliery, Worksop, Notts 1862
638 TYLOR, ALFRED E., 123, Bute Street, Cardiff ... ... April 1, 1876
639 TYSON, WM. JOHN, 1, Lowther Street, Whitehaven ... ... Mar. 3, 1877
640 TYZACK, D., Kelung, Formosa Island, c/o Com. of Customs, Amoy, China Feb. 14, 1874
641 TYZACK, WILFRED, Tanfield Lea Coll., Lintz Green Station, Newcastle Oct. 7, 1876

642 URE, J. F., Engineer, Tyne Commissioners, Newcastle ... ... May 8, 1869
643 URWIN, ROBERT, Neville Hall, Newcastle-on-Tyne ... ... Sept. 1, 1877

644 VAUGHAN, CEDRIC, Hodbarrow Mines, Leyfield House, Millom, Cumb. Aug. 5, 1876
645 VIVIAN, JOHN, Diamond Boring Company, Whitehaven ... ... Mar. 3, 1877
646 VONDRACEK, VLADIMIR ... ... Aug. 1, 1874

647 WADHAM, E., C. and M.E., Millwood, Dalton-in-Furness ... ... Dec. 7, 1867
648 WAKE, H. H., River Wear Commissioners, Sunderland ... ... Feb. 3, 1872
649 WALKER, G. B., Wharncliffe Silkstone Collieries, Wortley, nr. Sheffield Dec. 2, 1871
650 WALKER, J. S., 15, Wallgate, Wigan, Lancashire ... ... Dec. 4, 1869
651 WALKER, W., Saltburn-by-the-Sea ... ... Mar. 5, 1870
652 WALLACE, HENRY, Trench Hall, Gateshead ... ... Nov. 2, 1872
653 WALTON, W., Upleatham Mines, Marske-by-the-Sea ... ... Feb. 1, 1867
654 WARD, H., Rodbaston Hall, near Penkridge, Stafford... ... ... Mar. 6, 1862
655 WARDALE, JOHN D., M.E., Redheugh Engine Works, Gateshead ... May 1, 1875
656 WARDELL, S. C., Doe Hill House, Alfreton ... ... April 1, 1865

ELECTED.

657 WARRINGTON, J., Worsborough Hall, near Barnsley ... ... Oct. 6, 1859
658 WATSON, H., High Bridge Works, Newcastle-on-Tyne ... ... Mar. 7, 1868
659 WATSON, H. B., High Bridge Works, Newcastle-on-Tyne ... ... Mar. 3, 1877
660 WATSON, M., Flimby and Broughton Moor Collieries, near Maryport.. Mar. 7, 1868
661 WEBSTER, R. C., Bangor Isycoed, near Wrexham, North Wales ... Sept. 6, 1855
662 WEEKS, J. G., Bedlington Colliery, Bedlington *(Member of Council)* Feb. 4, 1865
663 WESTMACOTT, P. G. B., Elswick Iron Works, Newcastle ... ... June 2, 1866
664 WHATELY, W. L., Wearmouth Colliery, Sunderland ... ... Dec. 4, 1875
665 WHITE, H., Weardale Coal Company, Towlaw, near Darlington ... 1866
666 WHITE, J. F., M.E., Wakefield ... ... July 2, 1872
667 WHITE, J. W. H., Woodlesford, near Leeds ... ... Sept. 2, 1876
668 WHITEHEAD, JAMES, Brindle Lodge, near Preston, Lancashire ... Dec. 4, 1875
669 WHITELAW, JOHN, 118, George Street, Edinburgh ... ... Feb. 5, 1870
670 WHITELAW, T., Shields and Dalzell Collieries, Motherwell ... ... April 6, 1872
671 WHITTEM, THOS. S., Wyken Colliery, near Coventry ... ... Dec. 5, 1874
672 WIDDAS, C., North Bitchburn Colliery, Howden, Darlington... ... Dec. 5, 1868
673 WIGHT, W. H., Cowpen Colliery, Blyth... ... ... Feb. 3, 1877
674 WILD, H. F., Stockport, Columbia County, New York, U.S. ... ... Oct. 3, 1874
675 WILD, J. G., Ellistown Colliery, Ellistown, near Leicester ... ... Oct. 5, 1867
676 WILLIAMS, E., Cleveland Lodge, Middlesbro' ... ... Sept. 2, 1865
677 WILLIAMS, J. J., Pantgwyn House, Holywell, Flintshire ... ... Nov. 2, 1872
678 WILLIAMSON, JOHN, Chemical Manufacturer, South Shields... ... Sept. 2, 1871
679 WILLIAMSON, JOHN, Cannock, &c., Collieries, Hednesford ... ... Nov. 2, 1872
680 WILLIS, J., 14, Portland Terrace, Newcastle-on-Tyne ... ... Mar. 5, 1857
681 WILSON, J., 69, Great Clyde Street, Glasgow... ... ... July 2, 1872
682 WILSON, J. B., Wingfield Iron Works and Colliery, Alfreton... ... Nov. 5, 1852
683 WILSON, ROBERT, Flimby Colliery, Maryport ... ... Aug. 1, 1874
684 WILSON, W. B., Kippax and Allerton Collieries, Leeds ... ... Feb. 6, 1869
685 WINTER, T. B., Grey Street, Newcastle-on-Tyne ... ... Oct. 7, 1871
686 WOOD, C. L., Freeland, Bridge of Earn, Perthshire 1853
687 WOOD, LINDSAY, Southill, Chester-le-Street (PAST PRESIDENT, *Member of Council)* ... ... Oct. 1, 1857
688 WOOD, THOMAS, Rainton House, Fence Houses ... ... Sept. 3, 1870
689 WOOD, W. H., West Hetton, Ferryhill 1856
690 WOOD, W. O., East Hetton Colliery, Coxhoe, Co. Durham ... ... Nov. 7, 1863
691 WOOLCOCK, HENRY, St. Bees, Cumberland ... ... Mar. 3, 1873
692 WRIGHT, G. H., 12, Trumpington Street, Cambridge ... ... July 2, 1872
693 WRIGHT, J. M., 20, Summerhill Terrace, Newcastle-on-Tyne ... Aug. 5, 1876
694 WRIGHTSON, T., Stockton-on-Tees ... ... Sept. 13, 1873

695 YOUNG, PHILIP, Cae-pen-ty Colliery, Frood, near Wrexham ... ... Oct. 11, 1873

Ordinary Members.

		ELECTED.
1	BELL, C. E., Park House, Durham	Dec. 3, 1870
2	BRAMALL, HENRY, M.I.C.E., St. Helen's, Lancashire	Oct. 5, 1878
3	DACRES, THOMAS, Dearham Colliery, Maryport	May 4, 1878
4	DIXON, JAMES S., 170, Hope Street, Glasgow	Aug. 3, 1878
5	ELLIS, W. R., F.G.S., Wigan	June 1, 1878
6	GILCHRIST, THOMAS, Eltringham, Prudhoe-on-Tyne	May 4, 1878
7	GOUDIE, J. H., Maryport Iron Works, Maryport	Sept. 7, 1878
8	HARDEN, JOHN HENRY, Phenix Iron Works, Phenixville, Chester County, Pennsylvania	June 1, 1878
9	KELLETT, WILLIAM, Wigan	June 1, 1878
10	LANCASTER, JOHN, Auchinheath, &c., Collieries, Lanarkshire ...	Sept. 7, 1878
11	LAURENCE, ARTHUR, 72, Crockherbtown, Cardiff	May 3, 1879
12	MARTIN, TOM PATTINSON, Allhallows Colliery, Mealsgate, Carlisle ...	Feb. 15, 1879
13	PEASE, J., White House, Penkridge	Mar. 2, 1878
14	ROGERS, WILLIAM, M.E., 19, King Street, Wigan	Nov. 2, 1878
15	RUSSELL, ROBERT, M.E., Coltness Iron Works, Newmains, N.B. ...	Aug. 3, 1878
16	SPENCER, JOHN W., Newburn, near Newcastle-on-Tyne	May 4, 1878
17	TOPPING, WALTER, Messrs. Cross, Tetley, & Co., Platt Bridge, Wigan	Mar. 2, 1878
18	WINSTANLEY, ROBT., M.E., Lancaster Avenue, Fennel St., Manchester	Sept. 7, 1878

Associate Members.

1	BACON, ARTHUR H., Murton Colliery, Sunderland	Nov. 3, 1877
2	BAILES, E. T., Wingate, Ferryhill	June 7, 1879
3	BELL, DOUGLAS M., Hendon Ropery, Sunderland	May 3, 1879
4	BRAGGE, G. S., Hucknall, Huthwaite, near Mansfield	July 2, 1872
5	BROUGH, THOMAS, Seaham Colliery, Seaham Harbour	Feb. 1, 1873
6	BROWN, M. W., Leamside Station, Fence Houses	Oct. 7, 1871
7	BROWN, W. B., Springfield, Wavertree, Liverpool	Mar. 2, 1878
8	BURNLEY, E. F., Whitwood Collieries, Normanton	April 11, 1874
9	CABRERA, FIDEL, c/o H. Kendall & Son, 12, Gt. Winchester St., London	Oct. 6, 1877
10	CHAMBERS, W. HENRY, 15, Victoria Road, Barnsley	Dec. 2, 1871
11	CLARK, ROBT., Garnant Collieries, Cwmaman, nr. Llanelly, So. Wales	Sept. 11, 1875
12	CLOUGH, JAMES, Bedlington Collieries, near Morpeth...	April 5, 1873
13	CLOVIS, LOUIS, 1, Borough Houses, Gateshead-on-Tyne	Feb. 15, 1879
14	COCHRANE, RALPH D., Hetton Colliery Offices, Fence Houses ...	June 1, 1878
15	DALZIEL, W. G., 2, Pembroke Terrace, Cardiff	Sept. 7, 1878
16	DOYLE, JOHN ELYOTT, B.A., St. Peter's Terrace, Birmingham ...	Mar. 1, 1879
17	DOYLE, PATRICK, C.E., F.M.S., F.L.S., M.R.A.S., Post Office, Rangoon	Mar. 1, 1879
18	EDEN, C. H., Sedgefield, Ferryhill	Sept. 13, 1873
19	EDGE, JOHN H., Coalport Wire Rope and Chain Works, Shifnal, Salop	Sept. 7, 1878
20	FENNELL, CORBY S., Ormside Rectory, Appleby, Westmorland ...	Mar. 2, 1878

ELECTED.

21 GAMBIER, G. G. C., South Hetton Colliery, Fence Houses ... ... Aug. 3, 1878
22 GERRARD, JAMES, Ince Hall Coal and Cannel Company, Wigan ... Mar. 3. 1873
23 GREENER, T. Y., Rainford Collieries, St. Helen's, Lancashire... ... July 2, 1872
24 GREENER, W. J., Pemberton Colliery, Wigan ... ... Mar. 2, 1878
25 GRESLEY, W. S., Overseale, Ashby-de-la-Zouch ... ... Oct. 5, 1878
26 HAMILTON, E., Rig Wood, Saltburn-by-the-Sea ... ... Nov. 1, 1873
27 HARRISON, J. W., M.E., Gildersome, near Leeds ... ... Aug. 3, 1878
28 HUGHES, E. G., Solway View, Whitehaven ... ... June 1, 1878
29 HUMBLE, STEPHEN, Uttoxeter Road, Derby ... ... Oct. 6, 1877
30 JEPSON, H., Stanley, near Wakefield ... ... July 2, 1872
31 JOHNSON, W., Abram Colliery, Wigan ... ... Feb. 14, 1874
32 LISLE, J., Washington Colliery, County Durham ... ... July 2, 1872
33 LYON, JAMES, Vale View, Whitehaven ... ... Mar. 3, 1877
34 MILLER, D. S., Wearmouth Colliery, Sunderland ... ... Nov. 7, 1874
35* MILLER, NATHAN, Kurhurballa Collieries, East India Railway, Chord Line, Bengal ... ... Oct. 5, 1878
36 PRICHARD, WM., Navigation and Deep Duffryn Collieries, Mountain Ash, South Wales ... ... Dec. 7, 1878
37 RATHBONE, EDGAR P., 662, Weingasse II., Freiburg, Saxon ... ... Mar. 7, 1874
38 RYLANDS, RICHARD A., Haford Las, Minera, Wrexham ... ... June 1, 1878
39 SAISE, WALT., D. Sc., Assist. Manager E. I .R. Collieries, Sindi, Bengal Nov. 3, 1877
40 SAWYER, A. R., Ass. R.S.M., Stone, Stafford ... ... Dec. 6, 1873
41 SEYMOUR, T. M., Lambton Colls., Waratah, nr. Newcastle, New S. Wales Dec. 4, 1875
42 SMITH, J. BAGNOLD, The Laurels, Chesterfield... ... ... Nov. 2, 1878
43 STONES, T. H.. Wigan Coal & Iron Co., Westleigh, nr. Leigh, Lancashire Nov. 7, 1874
44 SUTHERST, JOHN, Cleveland Foundry, Guisbro' ... ... Dec. 1, 1877
45 THOMPSON, JOHN, Heworth Colliery, County Durham ... ... Dec. 7, 1878
46 WINTER, THOMAS, Messrs. Tangye Brothers & Steel, Swansea ... Mar. 2, 1878

Students.

1 ARMITAGE, MATTHEW, Birtley, near Chester-le-Street ... ... Oct. 6, 1877
2 ATKINSON, A. A., Munglepore Colliery, Bengal, India ... ... Aug. 3, 1878
3 ATKINSON, E. E., Hebburn Colliery, near Newcastle-on-Tyne ... Nov. 4, 1876
4 ATKINSON, F. R., Haswell Colliery, Fence Houses ... ... Feb. 14, 1874
5 AYTON, E. F., Lumley Colliery, Fence Houses ... ... Feb. 5, 1876
6 AYTON, HENRY, Seaton Delaval Colliery, Dudley, Northumberland ... Mar. 6, 1875

7 BARNES, A. W., Grassmore Colliery, near Chesterfield ... ... Oct. 5, 1872
8 BARRETT, CHARLES ROLLO, Burnhope House, Lanchester ... ... Nov. 7, 1874
9 BERKLEY, R. W., Marley Hill Colliery, Gateshead ... ... Feb. 14, 1874
10 BEWICK, T. B., Haydon Bridge, Northumberland ... ... Mar. 7, 1874
11 BIRD, HARRY, Haydon Bridge, Northumberland ... ... April 7, 1877
12 BIRD, W. J., Wingate Colliery, Durham ... ... Nov. 6, 1875
13 BLACKETT, W. C., 6, Old Elvet, Durham ... ... Nov. 4, 1876

14 BLAKELEY, A. B., Hollyroyd, Dewsbury ... ... Feb. 15, 1879
15 BOWLKER, T. J., Heddon Vicarage, Wylam-on-Tyne ... ... May 5, 1877

ELECTED.

16 BROWN, C. GILPIN, Hetton Colliery, Fence Houses ... ... Nov. 4, 1876
17 BRUCE, JOHN, 2, Framlington Place, Newcastle-on-Tyne ... ... Feb. 14, 1874
18 BUCKHAM, ROBERT, East Pontop Colliery, Lintz Green ... ... Oct. 5, 1878
19 BULMAN, G. H., Ryhope Colliery, Sunderland ... ... April 11, 1874
20 BULMAN, H. F., 10, Framlington Place, Newcastle-on-Tyne ... ... May 2, 1874
21 BUNNING, C. Z., Ryton-on-Tyne ... ... Dec. 6, 1873

22 CALDWELL, JOHN S., The Grove, Westhoughton, near Bolton, Lan. ... Nov. 7, 1874
23 CANDLER, T. E., East Lodge, Crook, Darlington ... ... May 1, 1875
24 CARR, CHARLES B., Castle Eden Colliery, County Durham ... ... May 6, 1876
25 CHILD, H., Whitkirk, Leeds ... ... Feb. 15, 1879
26 COBBOLD, C. H., San Valentino, Abruzzo, Citenone, Italy ... ... May 3, 1873
27 COCKBURN, W. C., 8, Summerhill Grove, Newcastle-on-Tyne ... ... July 2, 1872
28 COX, L. CLIFFORD, Ravenstone, near Ashby-de-la-Zouch ... ... April 1, 1876
29 CRAIG, ERNEST, Silksworth Colliery, near Sunderland ... ... Nov. 3, 1877
30 CRAWFORD, T. W., Lofthouse Station Collieries, near Wakefield ... Dec. 4, 1875
31 CRONE, F. E., Killingworth House, near Newcastle ... ... Sept. 2, 1876

32 DAVIDSON, C. C., Ore Bank House, Bigrigg, *via* Carnforth, Cumberland Nov. 4, 1876
33 DAVIS, KENNETH M., Towneley and Stella Collieries, Ryton-on-Tyne April 5, 1879
34 DEPLEDGE, M. F., Brancepeth, near Durham ... ... April 7, 1877
35 DODD, MICHAEL, Jun., Heddon Colliery, Wylam-on-Tyne ... ... Dec. 4, 1875
36 DONKIN, WM., Usworth Colliery, Washington Station, Co. Durham ... Sept. 2, 1876
37 DORMAN, FRANK, Esh Colliery, near Durham ... ... May 1, 1875
38 DOUGLAS, ARTHUR STANLEY, Harton Colliery, near South Shields ... June 1, 1878
39 DOWSON, W. C., Belle Vue House, Escomb, near Bishop Auckland ... Mar. 2, 1878
40 DUNN, A. F., Poynton, Stockport, Cheshire ... ... June 2, 1877
41 DURNFORD, H. ST. JOHN, Wharncliffe Silkstone Coll., Wortley, Sheffield June 2, 1877

42 EDGE, J. C., Ince Hall Coal and Cannel Company, Limited, Wigan ... Dec. 5, 1874
43 EVANS, DAVID L., Goldtops, Newport, Monmouthshire ... ... May 4, 1878

44 FENWICK, J. W., Bebside Colliery, Cowpen Lane, Northumberland ... Oct. 7, 1876
45 FLETCHER, JOHN E., Howbridge, Atherton, near Manchester ... Dec. 1, 1877
46 FORSTER, THOMAS E., Backworth, Newcastle-on-Tyne ... ... Oct. 7, 1876
47 FORSYTH, FRANK W., Lofthouse Station Colliery, Wakefield ... ... Dec. 2, 1876
48 FOWLER, ROBERT, Wearmouth Colliery, Sunderland ... ... Dec. 2, 1876
49 FRYAR, MARK, Walker Colliery, Newcastle-on-Tyne ... ... Oct. 7, 1876

50 GIBSON, W. F., 28, Northumberland Square, North Shields ... ... April 7, 1877
51 GILCHRIST, J. R., Newbottle Colliery Offices, Fence Houses ... ... Feb. 3, 1877
52 GORDON, CHAS., Longton Hall Colliery, Stoke-on-Trent ... ... May 5, 1877
53 GOULD, ALEX., Cowpen Colliery, Blyth ... ... Dec. 1, 1877
54 GUTHRIE, JAMES KENNETH, Ryton-on-Tyne ... ... Mar. 1, 1879

55 HADDOCK, W. T., Jun., Ryhope Colliery, Sunderland ... ... Oct. 7, 1876
56 HALLAS, G. H., Hindley Green Colliery, near Wigan ... ... Oct. 7, 1876
57 HALLIMOND, W. T., 12, Sutton Street, Durham ... ... May 2, 1874
58 HARRIS, W. S., Sheep Hill, Burnopfield, near Lintz Green ... ... Feb. 14, 1874

ELECTED.

59 HARRISON, ROBERT J., Mining Offices, Tynemouth ... ... May 1, 1875
60 HARRISON, R. W., Public Wharf, Leicester ... ... Mar. 3, 1877
61 HEDLEY, E., Rainham Lodge, The Avenue, Beckenham, Kent ... Dec. 2, 1871
62 HEDLEY, ERNEST H., West Chirton House, Percy Main ... ... Oct. 7, 1876
63 HEDLEY, SEPT. H., Londonderry Offices, Seaham Harbour ... ... Feb. 15, 1879
64 HENDY, J. C. B., Usworth Colliery, Washington Station, Co. Durham Sept. 2, 1876
65 HILL, LEONARD, No. 4, Brancepeth, Durham ... ... Oct. 6, 1877
66 HOLME, JAMES, 53, Breckfield Road South, Everton, Liverpool ... Sept. 11, 1875
67 HOWARD, WALTER, 13, Cavendish Street, Chesterfield ... ... April 13, 1878
68 HUDSON, JOSEPH S., Cambois Colliery, Blyth ... ... Mar. 2, 1878
69 HUMBLE, JOICEY, 17, Westmorland Terrace, Newcastle-on-Tyne ... Mar. 3, 1877
70 HUMBLE, ROBERT, 17, Westmorland Terrace, Newcastle-on-Tyne ... Sept. 2, 1876
71 HUNTER, JOHN P., Backworth Colliery, near Newcastle-on-Tyne ... Oct. 6, 1877

72 JOBLING, THOS. E., Coxlodge Colliery, by Kenton, Newcastle-on-Tyne Oct. 7, 1876
73 JORDAN, J. J., South Derwent Colliery, *via* Lintz Green ... ... Mar. 3, 1873

74 KAYLL, A. C., Felling Colliery, Gateshead ... ... Oct. 7, 1876
75 KIRKHOUSE, E. G., Medomsley, Newcastle-on-Tyne ... ... Aug. 3, 1878
76 KIRKUP, PHILIP, Peases' West Collieries, by Darlington ... ... Mar. 2, 1878
77 KIRTON, HUGH, Oxclose, Brancepeth, Durham... ... ... April 7, 1877

78 LEACH, C. C., Bedlington Collieries, Bedlington ... ... Mar. 7, 1874
79 LIDDELL, J. M., Colliery Office, Whitehaven ... ... Mar. 6, 1875
80 LINDSAY, CLARENCE S., Marsden, South Shields ... ... Mar. 4, 1876
81 LIVEING, E. H., Swiss Cottage, North Road, Durham... ... ... Sept. 1, 1877
82 LOCKE, ERNEST G., Peases' West Collieries, Crook, by Darlington ... Dec. 2, 1876
83 LONGBOTHAM, R. H., Framwellgate Colliery, near Durham ... ... Sept. 2, 1876

84 MACCABE, H. O., Chilton Colliery, Ferryhill ... ... Sept. 7, 1878
85 MADDISON, THOS. R., Thornhill Collieries, near Dewsbury ... ... Mar. 3, 1877
86 MAKEPEACE, H. R., Heworth Colliery Offices, Heworth, near Newcastle Mar. 3, 1877
87 MARKHAM, G. E., Howlish Offices, Bishop Auckland ... ... Dec. 4, 1875
88 MARSH, T. G., c/o W. Fisher, Burnt Tree House, Tipton, Staffordshire Sept. 13, 1873
89 MELLY, EDWARD F., Nunnery Colliery Offices, Sheffield ... ... Oct. 5, 1878
90 MOREING, C. A., 37, Spring Gardens, London ... ... Nov. 7, 1874
91 MUNDLE, ROBERT, Ryhope Colliery, Sunderland ... ... Mar. 6, 1875

92 NICHOLSON, JOS. C., Newbottle Colliery, Fence Houses ... ... Feb. 3, 1877
93 NOBLE, J. C., Usworth Hall, near Washington Station, Co. Durham... May 5, 1877

94 ORNSBY, R. E., Seaton Delaval Colliery, Dudley, Northumberland ... Mar. 6, 1875

95 PALMER, HENRY, Nunnery Colliery, Sheffield ... ... Nov. 2, 1878
96 PATTISON, JOS. W., Londonderry Offices, Seaham Harbour ... ... Feb. 15, 1879
97 PEAKE, CHARLES EDWD., Houghton Colliery, Barnsley ... ... Nov. 3, 1877
98 PEART, A. W., Cwmaman Colliery Offices, Aberdare ... ... Nov. 4, 1876
99 PICKERING, W. H., College of Physical Science, Newcastle ... ... Mar. 2, 1878

		ELECTED
100	PICKSTONE, WM., Oak Bank, Black Lane, near Manchester	Sept. 11, 1875
101	POCOCK, FRANCIS A., White Moss Colliery, near Ormskirk	Mar. 6, 1875
102	POTTER, E. A., Cramlington House, Northumberland	Feb. 6, 1875
103	POWELL, SAMUEL, Westminster Chambers, Wrexham...	June 1, 1878
104	PREST, J. J., Day's Terrace, Brotton	May 1, 1875
105	PRICE, STEPHEN RICHARD, Cwmaman Colliery, Aberdare, So. Wales	Nov. 3, 1877
106	PROCTOR, C. P., Killingworth Colliery, Newcastle	Oct. 7, 1876
107	REED, R., Cowpen Colliery, Blyth	Feb. 3, 1877
108	REES, ERNEST P., Langley Park Colliery, Durham	Mar. 4, 1876
109	RICHARDSON, R. W. P., 2, Ridley Street, Blackhill, Co. Durham ...	Mar. 4, 1876
110	ROBINSON, FRANK, College of Physical Science, Newcastle-on-Tyne...	Sept. 2, 1876
111	ROBINSON, GEO., Hebburn Colliery, near Newcastle-on-Tyne	Nov. 4, 1876
112	ROBSON, HARRY N., 3, North Bailey, Durham...	Dec. 4, 1875
113	ROBSON, THOS. O., 4, Campbell Street, Newcastle-on-Tyne	Sept. 11, 1875
114	ROUTLEDGE, W. H., Staveley Coal and Iron Co. Limited, Chesterfield	Oct. 7, 1876
115	SCARTH, R. W., Browney Colliery, Durham	Dec. 4, 1875
116	SCHIER, H. C., East Hetton Colliery Offices, Coxhoe, Co. Durham ...	Dec. 4, 1875
117	SCOTT, ALEX., Peases' West Collieries, by Darlington	Mar. 2, 1878
118	SCOTT, WM., Brancepeth Colliery Offices, Willington, Co. Durham ...	Mar. 4, 1876
119	SMITH, T. F., Jun., Cinderford Villas, near Newnham, Gloucestershire	May 5, 1877
120	SMITH, THOS., Leadgate, County Durham	Feb. 15, 1879
121	SOUTHERN, E. O., 5, Fenwick Terrace, Jesmond, Newcastle	Dec. 5, 1874
122	SOUTHERN, W. J., Northumberland House, Esplanade Grdns., Scarbro'	Aug. 1, 1874
123	SPENCE, R. F., Backworth Colliery, Newcastle-on-Tyne	Nov. 2, 1878
124	STOBART, F., Blue House, Washington, Co. Durham	Aug. 2, 1873
125	STOKER, ARTHUR P., Birtley, near Chester-le-Street	Oct. 6, 1877
126	TELFORD, W. H., Cramlington Colliery, Northumberland	Oct. 3, 1874
127	THOMPSON, WILLIAM	May 2, 1874
128	TODD, JOHN T., Hetton-le-Hole, Fence Houses...	Nov. 4, 1876
129	TOPHAM, EDWARD C., Silksworth Colliery, Sunderland	Nov. 3, 1877
130	TUCKER, A. W., Turk's Head Brewery, Gateshead	Dec. 2, 1876
131	VERNES, AMIDEE, 8, Claremont Place, Gateshead	May 4, 1878
132	WALKER, F. W., Harton Colliery, South Shields	Sept. 2, 1876
133	WALKER, SMART, Ryhope Colliery, near Sunderland	Dec. 4, 1875
134	WALTON, J. C., Heworth Colliery, near Newcastle-on-Tyne	Nov. 7, 1874
135	WHITE, C. E., Hebburn Colliery, near Newcastle-on-Tyne	Nov. 4, 1876
136	WILLIAMSON, J. E.	Nov. 7, 1874
137	WILSON, J. D., 8, Walker Terrace, Gateshead-on-Tyne	Sept. 11, 1875
138	WILSON, J. T., Blackhill, Richmond	Nov. 7, 1874
139	WOOD, A. E.	Dec. 2, 1876

Subscribing Collieries.

1 Ashington Colliery, Newcastle-on-Tyne.
2 Haswell Colliery, Fence Houses.
3 Hetton Collieries, Fence Houses.
4 Lambton Collieries, Fence Houses (Earl Durham).
5 North Hetton Colliery, Fence Houses.
6 Londonderry Collieries.
7 Ryhope Colliery, near Sunderland.
8 Seghill Colliery, Northumberland.
9 South Hetton and Murton Collieries.
10 Stella Colliery, Hedgefield, Blaydon-on-Tyne.
11 Throckley Colliery, Newcastle-on-Tyne.
12 Wearmouth Colliery, Sunderland.
13 Whitworth Colliery, Ferryhill.

CHARTER

OF

THE NORTH OF ENGLAND

Institute of Mining and Mechanical Engineers.

FOUNDED 1852.

INCORPORATED NOVEMBER 28TH, 1876.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland, Queen, Defender of the Faith, TO ALL TO WHOM THESE PRESENTS SHALL COME, GREETING:

WHEREAS it has been represented to us that NICHOLAS WOOD, of Hetton, in the County of Durham, Esquire (since deceased); THOMAS EMERSON FORSTER, of Newcastle-upon-Tyne, Esquire (since deceased); SIR GEORGE ELLIOT, Baronet (then George Elliot, Esquire), of Houghton Hall, in the said County of Durham, and EDWARD FENWICK BOYD, of Moor House, in the said County of Durham, Esquire, and others of our loving subjects, did, in the year one thousand eight hundred and fifty-two, form themselves into a Society, which is known by the name of "THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS," having for its objects the Prevention of Accidents in Mines and the Advancement of the Sciences of Mining and Engineering generally, of which Society LINDSAY WOOD, of Southill, Chester-le-Street, in the County of Durham, Esquire, is the present President. AND WHEREAS it has been further represented to us that the Society was not constituted for gain, and that neither its projectors nor Members derive nor have derived pecuniary profit from its prosperity; that it has during its existence of a period of nearly a quarter of a century steadily devoted itself to the preservation of human life and the safer development of mineral property; that it has contributed substantially and beneficially to the prosperity of the country and the welfare and happiness of the working members of the community; that the Society has since its establishment diligently

pursued its aforesaid objects, and in so doing has made costly experiments and researches with a view to the saving of life by improvements in the ventilation of mines, by ascertaining the conditions under which the safety lamp may be relied on for security; that the experiments conducted by the Society have related to accidents in mines of every description, and have not been limited to those proceeding from explosions; that the various modes of getting coal, whether by mechanical appliances or otherwise, have received careful and continuous attention, while the improvements in the mode of working and hauling belowground, the machinery employed for preventing the disastrous falls of roof underground, and the prevention of spontaneous combustion in seams of coal as well as in cargoes, and the providing additional security for the miners in ascending and descending the pits, the improvements in the cages used for this purpose, and in the safeguards against what is technically known as "overwinding," have been most successful in lessening the dangers of mining, and in preserving human life; that the Society has held meetings at stated periods, at which the results of the said experiments and researches have been considered and discussed, and has published a series of Transactions filling many volumes, and forming in itself a highly valuable Library of scientific reference, by which the same have been made known to the public, and has formed a Library of Scientific Works and Collections of Models and Apparatus, and that distinguished persons in foreign countries have availed themselves of the facilities afforded by the Society for communicating important scientific and practical discoveries, and thus a useful interchange of valuable information has been effected; that in particular, with regard to ventilation, the experiments and researches of the Society, which have involved much pecuniary outlay and personal labour, and the details of which are recorded in the successive volumes of the Society's Transactions, have led to large and important advances in the practical knowledge of that subject, and that the Society's researches have tended largely to increase the security of life; that the Members of the Society exceed 800 in number, and include a large proportion of the leading Mining Engineers in the United Kingdom. AND WHEREAS in order to secure the property of the Society, and to extend its useful operations, and to give it a more permanent establishment among the Scientific Institutions of our Kingdom, we have been besought to grant to the said LINDSAY WOOD, and other the present Members of the Society, and to those who shall hereafter become Members thereof, our Royal Charter of Incorporation. NOW KNOW YE that we, being desirous of encouraging a design so laudable and salutary, of our especial grace, certain

knowledge, and mere motion, have willed, granted, and declared, and do, by these presents, for us, our heirs, and successors, will, grant, and declare, that the said LINDSAY WOOD, and such others of our loving subjects as are now Members of the said Society, and such others as shall from time to time hereafter become Members thereof, according to such Bye-laws as shall be made as hereinafter mentioned, and their successors, shall for ever hereafter be, by virtue of these presents, one body, politic and corporate, by the name of "THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS," and by the name aforesaid shall have perpetual succession and a Common Seal, with full power and authority to alter, vary, break, and renew the same at their discretion, and by the same name to sue and be sued, implead and be impleaded, answer and be answered unto, in every Court of us, our heirs and successors, and be for ever able and capable in the law to purchase, acquire, receive, possess, hold, and enjoy to them and their successors any goods and chattels whatsoever, and also be able and capable in the law (notwithstanding the statutes of mortmain) to purchase, acquire, possess, hold and enjoy to them and their successors a hall or house, and any such other lands, tenements, or hereditaments whatsoever, as they may deem requisite for the purposes of the Society, the yearly value of which, including the site of the said hall or house, shall not exceed in the whole the sum of three thousands pounds, computing the same respectively at the rack rent which might have been had or gotten for the same respectively at the time of the purchase or acquisition thereof. AND WE DO HEREBY GRANT our especial license and authority unto all and every person and persons and bodies politic and corporate, otherwise competent, to grant, sell, alien, convey or devise in mortmain unto and to the use of the said Society and their successors, any lands, tenements, or hereditaments not exceeding with the lands, tenements or hereditaments so purchased or previously acquired such annual value as aforesaid, and also any moneys, stocks, securities, and other personal estate to be laid out and disposed of in the purchase of any lands, tenements, or hereditaments not exceeding the like annual value. AND WE FURTHER will, grant, and declare, that the said Society shall have full power and authority, from time to time, to sell, grant, demise, exchange and dispose of absolutely, or by way of mortgage, or otherwise, any of the lands, tenements, hereditaments and possessions, wherein they have any estate or interest, or which they shall acquire as aforesaid, but that no sale, mortgage, or other disposition of any lands, tenements, or hereditaments of the Society shall be made, except with the approbation and concurrence of a General Meeting. And our will

and pleasure is, and we further grant and declare that for the better rule and government of the Society, and the direction and management of the concerns thereof, there shall be a Council of the Society, to be appointed from among the Members thereof, and to include the President and the Vice-Presidents, and such other office-bearers or past office-bearers as may be directed by such Bye-laws as hereinafter mentioned, but so that the Council, including all *ex-officio* Members thereof, shall consist of not more than forty or less than twelve Members, and that the Vice-Presidents shall be not more than six or less than two in number. AND WE DO HEREBY FURTHER will and declare that the said LINDSAY WOOD shall be the first President of the Society, and the persons now being the Vice-Presidents and the Treasurer and Secretary, shall be the first Vice-Presidents, and the first Treasurer and Secretary, and the persons now being the Members of the Council shall be the first Members of the Council of the Society, and that they respectively shall continue such until the first election shall be made at a General Meeting in pursuance of these presents. AND WE DO HEREBY FURTHER will and declare that, subject to the powers by these presents vested in the General Meetings of the Society, the Council shall have the management of the Society, and of the income and property thereof, including the appointment of officers and servants, the definition of their duties, and the removal of any of such officers and servants, and generally may do all such acts and deeds as they shall deem necessary or fitting to be done, in order to carry into full operation and effect the objects and purposes of the Society, but so always that the same be not inconsistent with, or repugnant to, any of the provisions of this our Charter, or the Laws of our Realm, or any Bye-law of the Society in force for the time being. AND WE DO FURTHER will and declare that at any General Meeting of the Society, it shall be lawful for the Society, subject as hereinafter mentioned, to make such Bye-laws as to them shall seem necessary or proper for the regulation and good government of the Society, and of the Members and affairs thereof, and generally for carrying the objects of the Society into full and complete effect, and particularly (and without its been intended hereby to prejudice the foregoing generality), to make Bye-laws for all or any of the purposes hereinafter mentioned, that is to say: for fixing the number of Vice-Presidents, and the number of Members of which the Council shall consist, and the manner of electing the President and Vice-Presidents, and other Members of the Council, and the period of their continuance in office, and the manner and time of supplying any vacancy therein; and for regulating the times at which General Meetings of the Society and Meetings of the Council shall be held

and for convening the same and regulating the proceedings thereat, and for regulating the manner of admitting persons to be Members of the Society, and of removing or expelling Members from the Society, and for imposing reasonable fines or penalties for non-performance of any such Bye-laws, or for disobedience thereto, and from time to time to annul, alter, or change any such Bye-laws so always that all Bye-laws to be made as aforesaid be not repugnant to these presents, or to any of the laws of our Realm. AND WE DO FURTHER will and declare that the present Rules and Regulations of the Society, so far as they are not inconsistent with these presents, shall continue in force, and be deemed the Bye-laws of the Society until the same shall be altered by a General Meeting, provided always that the present Rules and Regulations of the Society and any future Bye-laws of the Society so to be made as aforesaid shall have no force or effect whatsoever until the same shall have been approved in writing by our Secretary of State for the Home Department. IN WITNESS WHEREOF WE HAVE CAUSED THESE OUR LETTERS TO BE MADE PATENT.

Witness Ourself at our Palace, at Westminster, this 28th day of November, in the fortieth year of our reign.

By Her Majesty's Command.

CARDEW.

THE NORTH OF ENGLAND INSTITUTE

OF

MINING AND MECHANICAL ENGINEERS.

BYE-LAWS

PASSED AT A GENERAL MEETING ON THE 16TH JUNE, 1877.

1.—The members of the North of England Institute of Mining and Mechanical Engineers shall consist of four classes, viz.:—Original Members, Ordinary Members, Associate Members, and Honorary Members, with a class of Students attached.

2.—ORIGINAL MEMBERS shall be those who were Ordinary Members on the 1st of August, 1877.

3.—ORDINARY MEMBERS.—Every candidate for admission into the class of Ordinary Members, or for transfer into that class, shall come within the following conditions:—He shall be more than twenty-eight years of age, have been regularly educated as a Mining or Mechanical Engineer, or in some other recognised branch of Engineering, according to the usual routine of pupilage, and have had subsequent employment for at least five years in some responsible situation as an Engineer, or if he has not undergone the usual routine of pupilage, he must have practised on his own account in the profession of an Engineer for at least five years, and have acquired a considerable degree of eminence in the same.

4.—ASSOCIATE MEMBERS shall be persons practising as Mining or Mechanical Engineers, or in some other recognised branch of Engineering, and other persons connected with or interested in Mining or Engineering.

5.—HONORARY MEMBERS shall be persons who have distinguished themselves by their literary or scientific attainments, or who have made important communications to the Society.

6.—Students shall be persons who are qualifying themselves for the profession of Mining or Mechanical Engineering, or some other of the recognised branches of Engineering, and such persons may continue Students until they attain the age of twenty-three years.

7.—The annual subscription of each Original Member, and of each Ordinary Member who was a Student on the 1st of August, 1877, shall be £2 2s., of each Ordinary Member (except as last mentioned) £3 3s., of each Associate Member £2 2s., and of each Student £1 1s., payable in advance, and shall be considered due on election, and afterwards on the first Saturday in August each year.

8.—Any Member may, at any time, compound for all future subscriptions by a payment of £25, where the annual subscription is £3 3s., and by a payment of £20 where the annual subscription is £2 2s. All persons so compounding shall be Original, Ordinary, or Associate Members for life, as the case may be; but any Associate Member for life who may afterwards desire to become an Ordinary Member for life, may do so, after being elected in the manner described in Bye-law 13, and on payment of the further sum of £5.

9.—Owners of Collieries, Engineers, Manufacturers, and Employers of labour generally, may subscribe annually to the funds of the Institute, and each such subscriber of £2 2s. annually shall be entitled to a ticket to admit two persons to the rooms, library, meetings, lectures, and public proceedings of the Society; and for every additional £2 2s., subscribed annually, two other persons shall be admissible up to the number of ten persons; and each such Subscriber shall also be entitled for each £2 2s. subscription to have a copy of the Proceedings of the Institute sent to him.

10.—In case any Member, who has been long distinguished in his professional career, becomes unable, from ill-health, advanced age, or other sufficient cause, to carry on a lucrative practice, the Council may, on the report of a Sub-Committee appointed for that purpose, if they find good reason for the remission of the annual subscription, so remit it. They may also remit any arrears which are due from a member, or they may accept from him a collection of books, or drawings, or models, or other contributions, in lieu of the composition mentioned in Bye-law 8, and may thereupon constitute him a Life Member, or permit him to resume his former rank in the Institute.

11.—Persons desirous of becoming Ordinary Members shall be proposed and recommended, according to the Form A in the Appendix, in which form the name, usual residence, and qualifications of the candidate shall be distinctly specified. This form must be signed by the proposer and at least five other Members certifying a personal knowledge of the candidate. The proposal so made being delivered to the Secretary, shall be submitted to the Council, who on approving the qualifications shall determine if the candidate is to be presented for ballot, and if it is so deter-

mined, the Chairman of the Council shall sign such approbation. The same shall be read at the next Ordinary General Meeting, and afterwards be placed in some conspicuous situation until the following Ordinary General Meeting, when the candidate shall be balloted for.

12.—Persons desirous of being admitted into the Institute as Associate Members, or Students, shall be proposed by three Members; Honorary Members shall be proposed by at least five Members, and shall in addition be recommended by the Council, who shall also have the power of defining the time during which, and the circumstances under which, they shall be Honorary Members. The nomination shall be in writing, and signed by the proposers (according to the Form B in the Appendix), and shall be submitted to the first Ordinary General Meeting after the date thereof. The name of the person proposed shall be exhibited in the Society's room until the next Ordinary General Meeting, when the candidate shall be balloted for.

13.—Associate Members or Students, desirous of becoming Ordinary Members, shall be proposed and recommended according to the Form C in the Appendix, in which form the name, usual residence, and qualifications of the candidate shall be distinctly specified. This form must certify a personal knowledge of the candidate, and be signed by the proposer and at least two other Members, and the proposal shall then be treated in the manner described in Bye-law 11. Students may become Associate Members at any time after attaining the age of twenty-three on payment of an Associate Member's subscription.

14.—The balloting shall be conducted in the following manner:—Each Member attending the Meeting at which a ballot is to take place shall be supplied (on demand) with a list of the names of the persons to be balloted for, according to the Form D in the Appendix, and shall strike out the names of such candidates as he desires shall not be elected, and return the list to the scrutineers appointed by the presiding Chairman for the purpose, and such scrutineers shall examine the lists so returned, and inform the meeting what elections have been made. No candidate shall be elected unless he secures the votes of two-thirds of the Members voting.

15.—Notice of election shall be sent to every person within one week after his election, according to the Form E in the Appendix, enclosing at the same time a copy of Form F, which shall be returned by the person elected, signed, and accompanied with the amount of his annual subscription, or life composition, within two months from the date of such election, which otherwise should become void.

16.—Every Ordinary Member elected having signed a declaration in the Form F, and having likewise made the proper payment, shall receive a certificate of his election.

17.—Any person whose subscription is two years in arrear shall be reported to the Council, who shall direct application to be made for it, according to the Form G in the Appendix, and in the event of its continuing one month in arrear after such application, the Council shall have the power, after remonstrance by letter, according to the Form H in the Appendix, of declaring that the defaulter has ceased to be a member.

18.—In case the expulsion of any person shall be judged expedient by ten or more Members, and they think fit to draw up and sign a proposal requiring such expulsion, the same being delivered to the Secretary, shall be by him laid before the Council for consideration. If the Council, after due inquiry, do not find reason to concur in the proposal, no entry thereof shall be made in any minutes, nor shall any public discussion thereon be permitted, unless by requisition signed by one-half the Members of the Institute; but if the Council do find good reason for the proposed expulsion, they shall direct the Secretary to address a letter, according to the Form I in the Appendix, to the person proposed to be expelled, advising him to withdraw from the Institute. If that advice be followed, no entry on the minutes nor any public discussion on the subject shall be permitted; but if that advice be not followed, nor an explanation given which is satisfactory to the Council, they shall call a General Meeting for the purpose of deciding on the question of expulsion; and if a majority of the persons present at such Meeting (provided the number so present be not less than forty) vote that such person be expelled, the Chairman of that Meeting shall declare the same accordingly, and the Secretary shall communicate the same to the person, according to the Form J in the Appendix.

19.—The Officers of the Institute, other than the Treasurer and the Secretary, shall be elected from the Original, Ordinary, and Associate Members, and shall consist of a President, six Vice-Presidents, and eighteen Councillors, who, with the Treasurer and the Secretary (if Members of the Institute) shall constitute the Council. The President, Vice-Presidents, and Councillors shall be elected at the Annual Meeting in August (except in cases of vacancies) and shall be eligible for re-election, with the exception of any President or Vice-President who may have held office for three immediately preceding years, and such six Councillors as may have attended the fewest Council Meetings during the past

year; but such Members shall be eligible for re-election after being one year out of office.

20.—The Treasurer and the Secretary shall be appointed by the Council, and shall be removable by the Council, subject to appeal to a General Meeting. One and the same person may hold both these offices.

21.—Each Original, Ordinary, and Associate Member shall be at liberty to nominate in writing, and send to the Secretary not less than eight days prior to the Ordinary General Meeting in June, a list, duly signed, of Members suitable to fill the offices of President, Vice-Presidents, and Members of Council, for the ensuing year. The Council shall prepare a list of the persons so nominated, together with the names of the Officers for the current year eligible for re-election, and of such other Members as they deem suitable for the various offices. Such list shall comprise the names of not less than thirty. The list so prepared by the Council shall be submitted to the General Meeting in June, and shall be the balloting list for the annual election in August. (See Form K in the Appendix.) A copy of this list shall be posted at least seven days previous to the Annual Meeting, to every Original, Ordinary, and Associate Member; who may erase any name or names from the list, and substitute the name or names of any other person or persons eligible for each respective office; but the number of persons on the list, after such erasure or substitution, must not exceed the number to be elected to the respective offices. Papers which do not accord with these directions shall be rejected by the scrutineers. The Votes for any Members who may not be elected President or Vice-Presidents shall count for them as Members of the Council. The Chairman shall appoint four scrutineers, who shall receive the balloting papers, and, after making the necessary scrutiny, destroy the same, and sign and hand to the Chairman a list of the elected Officers. The balloting papers may be returned through the post, addressed to the Secretary, or be handed to him, or to the Chairman of the Meeting, so as to be received before the appointment of the scrutineers for the election of Officers.

22.—In case of the decease or resignation of any Officer or Officers, the Council, if they deem it requisite that the vacancy shall be filled up, shall present to the next Ordinary General Meeting a list of persons whom they nominate as suitable for the vacant offices, and a new Officer or Officers shall be elected at the succeeding Ordinary General Meeting.

23.—The President shall take the chair at all meetings of the Institute, the Council, and Committees, at which he is present (he being *ex-officio* a member of all), and shall regulate and keep order in the proceedings.

24.—In the absence of the President, it shall be the duty of the senior Vice-President present to preside at the meetings of the Institute, to keep order, and to regulate the proceedings. In case of the absence of the President and of all the Vice-Presidents, the meeting may elect any Member of Council, or in case of their absence, any Member present, to take the chair at the meeting.

25.—The Council may appoint Committees for the purpose of transacting any particular business, or of investigating specific subjects connected with the objects of the Institute. Such Committees shall report to the Council, who shall act thereon as they see occasion.

26.—The Treasurer and the Secretary shall act under the direction and control of the Council, by which body their duties shall from time to time be defined.

27.—The Funds of the Society shall be deposited in the hands of the Treasurer, and shall be disbursed or invested by him according to the direction of the Council.

28.—The Copyright of all papers communicated to, and accepted for printing by the Council, and printed within twelve months, shall become vested in the Institute, and such communications shall not be published for sale or otherwise, without the written permission of the Council.

29.—An Ordinary General Meeting shall be held on the first Saturday of every month (except January and July) at two o'clock, unless otherwise determined by the Council; and the Ordinary General Meeting in the month of August shall be the Annual Meeting, at which a report of the proceedings, and an abstract of the accounts of the previous year, shall be presented by the Council. A Special General Meeting shall be called whenever the Council may think fit, and also on a requisition to the Council, signed by ten or more Members. The business of a Special Meeting shall be confined to that specified in the notice convening it.

30.—At meetings of the Council, five shall be a quorum. The minutes of the Council's proceedings shall be at all times open to the inspection of the Members.

31.—All Past-Presidents shall be *ex-officio* Members of the Council so long as they continue Members of the Institute, and Vice-Presidents who have not been re-elected or have become ineligible from having held office for three consecutive years, shall be *ex-officio* Members of the Council for the following year.

32.—Every question, not otherwise provided for, which shall come before any Meeting, shall be decided by the votes of the majority of the Original, Ordinary, and Associate Members then present.

33.—All papers shall be sent for the approval of the Council at least twelve days before a General Meeting, and after approval, shall be read before the Institute. The Council shall also direct whether any paper read before the Institute shall be printed in the Transactions, and notice shall be given to the writer within one month after it has been read, whether it is to be printed or not.

34.—All proofs of reports of discussions, forwarded to Members for correction, must be returned to the Secretary within seven days from the date of their receipt, otherwise they will be considered correct and be printed off.

35.—The Institute is not, as a body, responsible for the statements and opinions advanced in the papers which may be read, nor in the discussions which may take place at the meetings of the Institute.

36.—Twelve copies of each paper printed by the Institute shall be presented to the author for private use.

37.—Members elected at any meeting between the Annual Meetings shall be entitled to all papers issued in that year, so soon as they have signed and returned Form F, and paid their subscriptions.

38.—The Transactions of the Institute shall not be forwarded to Members whose subscriptions are more than one year in arrear.

39.—No duplicate copies of any portion of the Transactions shall be issued to any of the Members unless by written order from the Council.

40.—Invitations shall be forwarded to any person whose presence at the discussions the Council may think advisable, and strangers so invited shall be permitted to take part in the proceedings but not to vote. Any Member of the Institute shall also have power to introduce two strangers (see Form L) to any General Meeting, but they shall not take part in the proceedings except by permission of the Meeting.

41.—No alteration shall be made in the Bye-laws of the Institute, except at the Annual Meeting, or at a Special Meeting for that purpose, and the particulars of every such alteration shall be announced at a previous Ordinary Meeting, and inserted in its minutes, and shall be exhibited in the room of the Institute fourteen days previous to such Annual or Special Meeting, and such Meeting shall have power to adopt any modification of such proposed alteration of the Bye-laws.

Approved,
R. ASSHETON CROSS.

Whitehall,
2nd July, 1877.

APPENDIX TO THE BYE-LAWS.

[FORM A.]

A. B. [Christian Name, Surname, Occupation, and Address in full], being upwards of twenty-eight years of age, and desirous of being elected an Ordinary Member of the North of England Institute of Mining and Mechanical Engineers, I recommend him from *personal knowledge* as a person in every respect worthy of that distinction, because—

[*Here specify distinctly the qualification of the Candidate, according to the spirit of Bye-law 3.*]

On the above grounds, I beg leave to propose him to the Council as a proper person to be admitted an Ordinary Member.

Signed_____ Member.

Dated this day of 18

We, the undersigned, concur in the above recommendation, being convinced that A. B. is in every respect a proper person to be admitted an ordinary Member.

FROM PERSONAL KNOWLEDGE.

_____
_____
_____ } Five Members.
_____
_____

[*To be filled up by the Council.*]

The Council, having considered the above recommendation, present A. B. to be balloted for as a of the North of England Institute of Mining and Mechanical Engineers.

Signed_____ Chairman.

Dated this day of 18

[FORM B.]

A. B. [Christian Name, Surname, Occupation, and Address in full], being desirous of admission into the North of England Institute of Mining and Mechanical Engineers, we, the undersigned, propose and recommend that he shall become [an Honorary Member, or an Associate Member, or a Student] thereof.

_____
_____
_____ } Three* Members.
_____
_____

* If an Honorary Member, five signatures are necessary, and the following Form must be filled in by the Council.

Dated this day of 18

[*To be filled up by the Council.*]

The Council, having considered the above recommendation, present A. B. to be balloted for as an Honorary Member of the North of England Institute of Mining and Mechanical Engineers.

Signed_____ Chairman.

Dated day of 18

[FORM C.]

A. B. [Christian Name, Surname, Occupation, and Address in full], being at present a of the North of England Institute of Mining and Mechanical Engineers, and upwards of twenty-eight years of age, and being desirous of becoming an Ordinary Member of the said Institute, I recommend him, from *personal knowledge*, as a person in every respect worthy of that distinction, because—

[*Here specify distinctly the Qualifications of the Candidate according to the spirit of Bye-law 3.*]

On the above grounds, I beg leave to propose him to the Council as a proper person to be admitted an Ordinary Member.

Signed_____ Member.

Dated this day of 18

We, the undersigned, concur in the above recommendation, being

convinced that A. B. is in every respect a proper person to be admitted an Ordinary Member.

FROM PERSONAL KNOWLEDGE.

_____ } Two
_____ } Members.

[*To be filled up by the Council.*]

The Council, having considered the above recommendation, present A. B. to be balloted for as an Ordinary Member of the North of England Institute of Mining and Mechanical Engineers.

Signed_____ Chairman.

Dated day of 18

[FORM D.]

List of the names of persons to be balloted for at the Meeting on , the day of 18

ORDINARY MEMBERS:—

_____
_____
_____

ASSOCIATE MEMBERS:—

_____
_____

HONORARY MEMBERS:—

_____
_____

STUDENTS:—

_____
_____

Strike out the names of such persons as you desire should *not* be elected, and hand the list to the Chairman.

[FORM E.]

SIR, I beg leave to inform you that on the day of you were elected a of the North of England Institute of Mining and Mechanical Engineers, but in conformity with its Rules your election cannot be confirmed until the enclosed form be returned to me

with your signature, and until your first annual subscription be paid, the amount of which is £ , or, at your option, the life-composition of £

If the subscription is not received within two months from the present date, the election will become void under Bye-law 15.

I am, Sir,

Yours faithfully,

Secretary.

Dated 18

[FORM F.]

I, the undersigned, being elected a of the North of England Institute of Mining and Mechanical Engineers, do hereby agree that I will be governed by the Charter and Bye-laws of the said Institute for the time being; and that I will advance the objects of the Institute as far as shall be in my power, and will not aid in any unauthorised publication of the proceedings, and will attend the meetings thereof as often as I conveniently can; provided that whenever I shall signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) cease to be a Member.

Witness my hand this day of 18

[FORM G.]

Sir,—I am directed by the Council of the North of England Institute of Mining and Mechanical Engineers to draw your attention to Bye-law 17, and to remind you that the sum of £ of your annual subscriptions to the funds of the Institute remains unpaid, and that you are in consequence in arrear of subscription. I am also directed to request that you will cause the same to be paid without further delay, otherwise the Council will be under the necessity of exercising their discretion as to using the power vested in them by the article above referred to.

I am, Sir,

Yours faithfully,

Secretary.

Dated 18

[FORM H.]

SIR,—I am directed by the Council of the North of England Institute of Mining and Mechanical Engineers to inform you, that in consequence of non-payment of your arrears of subscription, and in pursuance of Bye-law 17, the Council have determined that unless payment of the amount £ is made previous to the day of next, they will proceed to declare that you have ceased to be a Member of the Institute.

But, notwithstanding this declaration, you will remain liable for payment of the arrears due from you.

I am, Sir,

Yours faithfully,

Secretary.

Dated 18

[FORM I.]

SIR,—I am directed by the Council of the North of England Institute of Mining and Mechanical Engineers to inform you that, upon mature consideration of a proposal which has been laid before them relative to you, they feel it their duty to advise you to withdraw from the Institute, or otherwise they will be obliged to act in accordance with Bye-law 18.

I am, Sir,

Yours faithfully,

Secretary.

Dated 18

[FORM J.]

SIR,—It is my duty to inform you that, under a resolution passed at a Special General Meeting of the North of England Institute of Mining and Mechanical Engineers, held on the day of 18 , according to the provisions of Bye-law 18, you have ceased to be a Member of the Institute.

I am, Sir,

Yours faithfully,

Secretary.

Dated 18

[FORM K.]

BALLOTING LIST.

Ballot to take place at the Meeting of 18 at Two o'Clock.

PRESIDENT—ONE NAME only to be returned, or the vote will be lost.

——— President for the current year eligible for re-election.

——— } New Nominations.
——— }

VICE-PRESIDENTS—SIX NAMES only to be returned, or the vote will be lost.

The Votes for any Members who may not be elected as President or Vice-Presidents will count for them as other Members of the Council.

——— }
——— }
——— } Vice-Presidents for the current year eligible for re-election.
——— }

——— }
——— }
——— } New Nominations.
——— }

COUNCIL—EIGHTEEN NAMES only to be returned, or the vote will be lost.

——— }
——— }
——— }
——— }
——— }
——— } Members of the Council for the current year eligible for re-election.
——— }
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——— }
——— } New Nominations.
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Any list returned with a greater number of Names than
ONE PRESIDENT,
SIX VICE-PRESIDENTS,
EIGHTEEN COUNCILLORS,
Will be rejected by the Scrutineers as informal, and the Votes will consequently be lost.

Extract from Bye-law 21.

Each Original, Ordinary, and Associate Member shall be at liberty to nominate in writing, and send to the Secretary not less than eight days prior to the Ordinary General Meeting in June, a list, duly signed, of Members suitable to fill the Offices of President, Vice-Presidents, and Members of Council, for the ensuing year. The Council shall prepare a list of the persons so nominated, together with the names of the Officers for the current year eligible for re-election, and of such other Members as they deem suitable for the various offices. Such list shall comprise the names of not less than thirty. The list so prepared by the Council shall be submitted to the General Meeting in June, and shall be the balloting list for the annual election in August. (See Form K in the Appendix.) A copy of this list shall be posted at least seven days

previous to the Annual Meeting, to every Original, Ordinary, and Associate Member; who may erase any name or names from the list, and substitute the name or names of any other person or persons eligible for each respective office; but the number of persons on the list, after such erasure or substitution, must not exceed the number to be elected to the respective offices. Papers which do not accord with these directions shall be rejected by the Scrutineers. The votes for any Members who may not be elected President or Vice-Presidents shall count for them as Members of the Council. The Chairman shall appoint four Scrutineers, who shall receive the balloting papers, and after making the necessary scrutiny destroy the same, and sign and hand to the Chairman a list of the elected Officers. The balloting papers may be returned through the post, addressed to the Secretary, or be handed to him, or to the Chairman of the Meeting, so as to be received before the appointment of the Scrutineers for the election of Officers.

_____

_____

_____

_____

Names substituted for any of the above are to be written in the blank spaces opposite those they are intended to supersede.

The following Members are ineligible from causes specified in Bye-law 19:—

As PRESIDENT _____

As VICE-PRESIDENT _____

As COUNCILLORS _____

[FORM L.]

Admit

of

to the Meeting on Saturday, the

(Signature of Member or Student)

The Chair to be taken at Two o'Clock.

I undertake to abide by the Regulations of the North of England Institute of Mining and Mechanical Engineers, and not to aid in any unauthorised publication of the Proceedings.

(Signature of Visitor)

Not transferable.

NORTH OF ENGLAND INSTITUTE

OF

MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING, SATURDAY, SEPT. 7TH, 1878, IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE.

G. C. GREENWELL, ESQ., PRESIDENT, IN THE CHAIR.

The ASSISTANT SECRETARY read the minutes of the last meeting and the minutes of the Council meetings.

The following gentlemen were elected:—

HONORARY MEMBER—

M. VUILLEMIN, Engineer and General Director of the Mines at Aniche, and Vice-President of the Societé de l'Industrie Minerale, France.

ORDINARY MEMBERS—

Mr. ROBERT WINSTANLEY, M.E., Manchester.

Mr. JAMES HUNTER GOUDIE, Engineer, Maryport Iron Works.

Mr. JOHN LANCASTER, M.E., Auchinbeath, &c., Collieries, Lanarkshire.

ASSOCIATES—

Mr. W. GASCOYNE DALZIEL, M.E., 2, Pembroke Terrace, Cardiff.

Mr. JOHN EDGE, Colebrook Dale, Salop, Shropshire.

STUDENT—

Mr. H. O. MACCABE, M.E., Chilton Colliery, Ferry Hill.

The following were nominated for election at the next meeting :—

ORDINARY MEMBER—

Mr. HENRY BRAMALL, Mem. Inst. C.E., St. Helens, Lancashire.

ASSOCIATES—

Mr. NATHAN MILLER, Kurhurballa Collieries, East India Railway, Chord Line, Bengal.

Mr. W. S. GRESLEY, M.E., Overseale, Ashby-de-la-Zouch.

STUDENTS—

Mr. ROBERT BUCKHAM, East Pontop Colliery, Lintz Green.

Mr. EDWARD F. MELLY, Nunnery Colliery Offices, Sheffield.

Mr. G. A. LEBOUR having been called upon to read his "Notes on some of the Sections of the Carboniferous Limestone Series of Northumberland, published by the Institute in the first Part of the 'Account of Borings and Sinkings,'" said, that with the permission of the Chairman he would ask the meeting to take the notes as read, as they referred to the sections published, and would, if read apart from those sections, be almost unintelligible; and he did so the more readily as the other paper on the programme was one of considerable length and importance, and the author had, he believed, travelled a very long distance to read it.

The meeting, having been consulted, agreed to Mr. Lebour's proposition, and the following paper was considered as read:—

BRIEF NOTES ON SOME OF THE SECTIONS OF THE CARBONIFEROUS LIMESTONE SERIES OF NORTHUMBERLAND, PUBLISHED IN THE FIRST PART OF THE "ACCOUNT OF BORINGS AND SINKINGS."

By G. A. LEBOUR,

Member of the Institute, F.G.S., Lecturer in Geological Surveying in the University of Durham College of Physical Science, Newcastle.

The following short memoranda may, it is thought, add somewhat to the interest of the more obscure sections contained in the first batch of boring accounts just issued by the Institute. They may serve to direct the attention of members having special knowledge, or special opportunities, to some points in local geology which require and deserve elucidation.

The stratigraphical nomenclature adopted is that proposed by the writer in 1876, in his paper "On the larger divisions of the Carboniferous System in Northumberland."*

The numbers are those of the sections, as given in the work referred to.

I.

No. 6.—ACOMB COLLIERY. (Page 4.)

The chief geological interest of this section lies in the drift deposits, especially the "strong clay" and "loamy sand" underlying the "gravel and stones." The two former divisions are well exposed in the tile works between the colliery and the North Tyne, by the side of the North British Railway, and consist of extremely finely laminated fresh-water sandy clay, more resembling the "warp" of Yorkshire than any other Northumbrian deposit known to the writer. The laminæ are so regular and thin as to be quite coherent, a peculiarity commoner in still-water sediments than in those of rapid rivers. Indeed, it is probable that the Acomb clay-beds are lacustrine in character, and represent the ooze of a small lake which once existed between the St. John Lee and Warden

* Transactions of the North of England Institute of Mining and Mechanical Engineers, Vol. XXV.

Hills, occupying (though at a higher level) much the same position as the recent alluvial haugh between the North and South Tyne rivers. No fossils have, to the writer's knowledge, been yet found in the clay; but it is probable that minute crustacean remains (Entomostraca) will be discovered in it on careful inspection.

The clay, as will be seen in the section, rests immediately on the denuded edges of the Bernician rocks, in the same manner as the Boulder clay of the district, with which it cannot, however, be compared. The overlying gravels belong to the series which form the well-marked terraces along the South Tyne valley, and which are but poorly represented along the North Tyne. So marked is this, that salmon fishers (who are well acquainted with the general appearance of the river-gravels in each valley) recognize the tilery pebbles at once as being of the South Tyne type. There is no passage between the gravel and the clay beyond the "loamy sand" mentioned in the section, but the beds are perfectly conformable.

In age the clays are then, it appears, intermediate between the Boulder clay proper and the high-level gravels of the South Tyne valley, which are themselves partly glacial in origin (containing striated pebbles in places) and partly post-glacial—that is, true river-gravels. The re-assortment of the glacial beds into the latter makes it often very difficult to distinguish the two kinds.

The fine leafy clay of Acomb may therefore be looked upon as a late inter-glacial deposit.

The "limestone" of the section is the Little Limestone (that next above the Great Limestone) of the Upper Bernician Series.*

II.

No. 8.—AID CRAG. (Page 7.)

This section is in the Lower Bernician beds, near the horizon of the Ridsdale Ironstone Shale. It was taken close to a fault of considerable throw, and its exact position with reference to the shale is somewhat doubtful in consequence. Properly it should be studied in connection with the sections of Ridsdale, Hareshaw, and Bellingham.

III.

Nos. 9-12.—ALLENSHEAD OR ALLEN'S CLOSE. (Pages 7-9.)

The place is now known usually as "Closehead."

* See Lebour "On the Little Limestone and its accompanying Coal in South Northumberland." (Transactions of the North of England Institute of Mining and Mechanical Engineers, Vol. XXIV., pages 72-83.)

The coal at the bottom of No. 9 has been worked on a small scale for land-sale purposes for a considerable number of years. It lies low down in the Lower Bernician series, and is liable to great variations of thickness in short distances, being at times nearly five feet thick. The immediate neighbourhood is, however, much faulted, and the seam is cut through by ancient washes or "stone dykes." The precise horizon of the beds here is open to discussion.

IV.

Nos. 44, 45.—BAMBOROUGH. (Pages 44, 45.)

These sections are in the Upper Bernician series, but their exact position within that series is not known. The intrusive sheets of the Whin Sill intersecting the district add to the difficulty of clearing up this point—an important one, since on it depends, to a great degree, the identification of the interesting beds with *Posidonomya Becheri* and plants at Budle. It is thought probable that the horizon may prove to be about that of the Little Limestone.

V.

Nos. 96-99.—BELLINGHAM. (Pages 83-85.)

No. 96 is an extremely detailed section of the Ridsdale ironstone shale, as it was measured in Hareshaw Burn. The ironstone varies very much in the size of its nodules, so that the separate thicknesses given can only be relied on for the particular spot at which they were measured. At the bottom of the first column of No. 97, the ironstone shale is given as a whole with a thickness of 29 feet. The "Isabella" and "Thomas" ironstones are continuous layers of clay ironstone below the Ridsdale shale, which were formerly worked as a "black band," with the intervening splint coal parting. These bands do not appear to be very constant. The limestone in this section is the Bottom Limestone of Ridsdale, a bed in the Lower Bernician series. At the Ridsdale Quarries a bed of sandstone alone intervenes between the limestone and the ironstone shale; this has been split up into the seven divisions of the present section (including a thin coal-seam) in a distance not exceeding five miles.

The shale heap at the mouth of No. 97 is rich in Bernician fossils, and especially in fine specimens of *Conularia quadrisulcata*, a form which is very rare elsewhere at the same horizon.

No. 98 is a section below the horizon of the ironstone shale, the Upper Hall seam being seven or eight fathoms beneath the latter.

No. 99.—The Hareshaw Head coal occurs still lower in the series than the last-mentioned seam. It is of excellent quality, and has long been worked for land-sale purposes.

VI.

Nos. 103–126.—BELSAY. (Pages 88–98.)

The identification of the exact position of these numerous shallow borings seems to be now almost impossible. All, however, refer to the Upper Bernician series from the Little Limestone coal upwards. In this district there is a great thickening of this uppermost portion of the series, and a number of seams above a foot thick are found between the Felltop and the Little Limestones, which are, further to the north and south, either mere scares of coal or altogether wanting.

VII.

Nos. 182–187.—BIRDHOPE CRAIG. (Pages 138–141.)

All these sections are low down in the Lower Bernician Rocks, much below the Ridsdale Series.

In No. 184, for "Sill Burn" read "Sills Burn." The latter is one of the streams running into the Redewater from the north. Its bed affords an admirable view of the beds or sills; hence the name.

VIII.

No. 188.—BIRKSHAW. (Page 141.)

The limestone in this section is the Little Limestone. See the writer's paper, already quoted, on that bed and its accompanying coal. (Transactions of the North of England Institute of Mining and Mechanical Engineers, Vol. XXIV.)

IX.

No. 288.—BRANDYWELL HALL. (Page 218.)

The "Blue and black stony clay, with whin tumblers or open limestone," appears to be Boulder clay resting upon the glaciated and eroded surface of the Little Limestone.

X.

No. 292.—BRINKBURN. (Pages 220, 221.)

This is a general section only, constructed from various borings or sinkings, and from surface observations. The account, therefore, although it may be correct in its parts, cannot be held to represent a true section of the beds at any one point.

For " Beadwell Limestone" read " Beadnell Limestone."

The Eight-Yard Limestone is that known south of this district as the Four-Fathom Limestone. The Main Coal here is the Shilbottle Seam.

XI.

No. 336.—BURRADON. (PAGE 252.)

The position of this section is a little to the South of Biddlestone Edge, and not far from the village of Netherton, at the foot of the Cheviots. It is specially interesting as being either at the very base of the Lower Bernician, or in the Tuedian or Calciferous Sandstone series, where measured sections are extremely scarce.

Mr. ARTHUR R. SAWYER, Assoc. R.S.M., then read the following Paper:—" Mining at Saarbrücken, with an Account of the Structure of the Coal-Field."

MINING AT SAARBRÜCKEN, WITH AN ACCOUNT OF THE STRUCTURE OF THE COAL-FIELD.

By A. R. SAWYER, Assoc. R.S.M.

The Saarbrücken Coal-field is one of the largest in Europe. The great number of faults and other irregularities, the presence of pyrites in the bands and cleat of the coal, to which many a fire is due, and the frequent occurrence of fire-damp, all tend to render the winning difficult.

I.—HISTORY.

Coal is first mentioned here in 1529, in an Act which secures all minerals, "also coals," to the manor of Saarbrücken. About the beginning of the eighteenth century, collieries are mentioned at Neunkirchen Wellesweiler, Bexbach, Friedrichsthal, Illingen, and Schwalbach; these were, however, worked on a small scale from adit levels or by means of shallow pits which were sunk until stopped by water.

By a princely decree of December 12th, 1754, all private "coal-diggings" became the property of Prince Wilhelm of Nassau-Saarbrücken, compensation being given, and were placed under the supervision of a manager and several under-viewers.

Coal was used till 1765, only for lime kilns; from that time it was used for house purposes; a little later for glassworks, etc.

During the French occupation the collieries were worked by the Republic from 1793–97, then given over to a Paris Company, and in 1808 placed under Imperial supervision.

By the treaty of 1815 they were handed over to Prussia, by whom they have been made the largest works under one management in the world. Under the energetic management of Leopold Sello, who was director of the Saarbrücken collieries from March, 1816, to October, 1857, the yearly output rose from 20,000 tons to 300,000 tons.

The first steam engine was put up in 1830; the first steam pumping and winding engines in 1838; haulage by steam was introduced in 1861,

and the first boring machines in 1867. In 1874 the Saarbrücken collieries yielded an output of 4,158,245 tons, and employed 21,000 workmen, 500 horses, and 199 steam engines equal to 10,300 horse-power.

II.—SITUATION OF THE COAL-FIELD AND EXTENT OF EXPOSED AREA OF COAL-MEASURES.

This coal-field lies south of the Hunsrück, and is bounded by the rivers Saar, Blies, and Nahe. (See Plates I., II., III., IV.) Its principal portion is on the right of the Saar, extending towards the Rhine; a very small portion being on the left. The greater part of the coal-field is situated in Rhenish Prussia, a small and valuable portion in Rhenish Bavaria, and another small portion in Lorraine. The exposed area of the Saarbrücken division of the coal-measures proper, which is the only important one commercially, has an oval shape, and is about ninety square miles in extent. The larger axis, which is about twenty-one miles long, has a N.E.E. direction; the smaller axis is about six miles long.

III.—GEOLOGICAL BOUNDARIES OF THE COAL-FIELD.

The line of contact between the Permian and the Devonian slates forms the northern boundary of the coal-field. The Devonian slates have here a southerly dip which is nearly vertical. The Permian lies against it with a gentle dip of from 18 degrees to 20 degrees to the south.

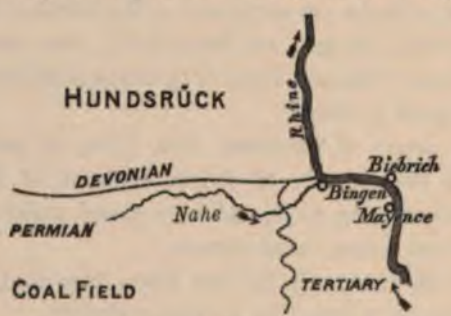


FIG. 1.

The prolongation of this line of contact falling in with the sudden bend of the Rhine from Biebrich to Bingen (see Fig 1.) leads to the belief in the existence of a great fault along that line.

The eastern boundary also seems to have been formed by a fault which was accompanied by an outflow of eruptive rock. Tertiary rocks occur on the other side of this boundary; they disclose Bunter between Oppenheim and Mayence.

Not only do eruptive rocks (Quartz Porphyry and Melaphyre) occur along the eastern boundary as at Kreuznach and the Donnersberg, but they

also occur at many other places, especially along the Nahe, beginning at Littermont. This constitutes an essential difference between the Saarbrücken coal-field and those of Westphalia and Belgium, in which no eruptive rocks occur; it bears analogy to the coal-field of Lower Silesia, in which eruptive rocks are found. There is conclusive evidence that the southern boundary, like the northern, is formed by a large dislocation of great thickness. The parallelism between those two boundaries is very great. More will be said about it in describing the lower group of seams in the Carboniferous formation.

In the west, the coal-measures pass under the Bunter. The borings made by the French, which proved coal-bearing strata about nine miles beyond the beginning of the Bunter, have not given very favourable results. The Bunter below the level of the valleys was found to be so impregnated with water, and so traversed by faults, that when of great thickness the sinking of pits through it meets with almost insurmountable difficulties. The Saarbrücken division of the coal-measures was also found to occur at a very great depth. Of forty boreholes, some of which reached a depth of over 1,800 feet, twenty-six have reached coal-bearing strata, some passing through nine seams. Eight have been abandoned too early. The remaining six were sunk in non-coal-bearing strata or younger formations; one of these, which was sunk at Coume to a depth of 338 feet, did not pass beyond the Muschelkalk.

The cost of sinking these boreholes is estimated at three million francs.

Boreholes sunk south of Forbach have proved failures. Those of Grossbliedersdorff, Alsting, Morsbach, Merlebach, Freyming, St. Avold, Longeville, and Oderfang, which were sunk to a great depth, remained either in the Bunter or passed into the Ottweiler division of the coal-measures. They all point to the presence of a large fault stretching east and west. The deepest of these holes, that of Freyming, passed through 758 feet of Bunter and 1,024 feet of Ottweiler strata.

IV.—GEOLOGICAL POSITION OF THE COAL-FIELD IN RELATION TO THOSE OF WESTPHALIA AND BELGIUM.

The Saarbrücken coal-field is situated on the southern slope of the immense mass of Devonian and Metamorphic slates, on the northern slope of which the Westphalian, the Belgian, and the Aix-la-Chapelle (Inde and Wurm), coal-fields lie stretched out.

These latter rest conformably on Mountain and Devonian limestones, and with these, present a wavy and zig-zagged structure. They are known to extend northwards under newer formations.

The older members of the Saarbrücken coal-field, on the contrary, are not known, nor has the coal-field been satisfactorily explored below the newer overlying formations.

Whether the mass of Devonian and Metamorphic slates assumed its present position before the formation of the coal-measures on its slopes; or whether the present coal-fields, which skirt these slopes, are the remains of a large carboniferous deposit which has been partly denuded away during the gradual rising of the slates, and accompanying submergence of the North Sea, is uncertain. The latter explanation seems the most probable.

V.—STRATA OVERLYING THE COAL-MEASURES.

The coal-measures are covered to the south and west by Triassic strata, and to the north and east by Permian strata.

The latter form, with the coal-measures, such an intimate system of stratification, that for a long time all the coal-bearing Permian strata were considered carboniferous. It may be remarked that just as here, so in the Kansas and in the eastern slopes of the Rocky Mountains, the Permian is so completely conformable to the carboniferous formation that no distinct line of demarcation can be drawn between them.

Permian strata, corresponding to the magnesian limestones and marl-slates here, do not occur.

The "Rothliegende," corresponding to the Permian lower red sandstones and marls here, is well represented.

The Triassic strata consist of three members: the Keuper, the Muschelkalk (wanting in England), and the Bunter. The Keuper is very insignificant in this coal-field, but the Muschelkalk and the Bunter are well developed.

The latter must once have covered the whole of the coal-measures, as may be inferred by outliers, many of which lie on the highest points. The coal-measures must already have been tilted, denuded, and traversed by faults before the deposition of the Bunter took place. The Bunter lies unconformably to the coal-measures, dipping in the opposite direction. The dip, which is S.S.E., is nearly horizontal. Faults and dykes do not pass from the coal-measures into the Bunter.

VI.—DETAILED DESCRIPTION OF THE NEWER (OVERLYING) FORMATIONS.

TRIAS.

1.—Bunter.—This being a shore deposit, consists principally of sandstones. The upper division of the Bunter is here called "Voltzia-sandstone," the lower, "Vosges-sandstone." (See Plate V.)

(a) VOSGES-SANDSTONE.—Its thickness is not known in Prussia, but in Bavaria it is 1,650 feet, and near Bitsch 990 feet. It is composed of sandstones and a few conglomerates. The sandstone is coarser than that of the Voltzia, and when firm is much used for building purposes. No fossil remains are known.

(b) VOLTZIA-SANDSTONE.—Its thickness is from twenty-six feet to sixty feet. The lower boundary is not distinct. The sandstones are fine-grained, and have been much quarried, being very good for building purposes. The uppermost strata of this division consist of beds of red and greenish blue clays, two to four feet thick, corresponding to the Röth of North Germany. The upper of these beds has a thickness of sometimes three feet, and is most constant, forming, with the Muschelkalk, a well-defined line of contact. The flora predominates over the fauna. The best examples have been found in quarries in the Krumbach valley between Goffontaine and Bischmishein, and are in the possession of the Saarbrücken Mining School.

The following are some of the species :—

Flora.—Voltzia heterophylla; Endolepis vulgaris and elegans; Anomopteris Mougeotii; Neuropteris intermedia, Caulopteris Voltzii; Equisetum Mougeotii (= Calamites arenaceous); Aethophyllum speciosum; Schizonema paradoxa.

Fauna.—Very scarce and badly preserved; Myacites; Myophoria; Rhizocorallium Jenense; Estheria minuta.

Galena and cerusite occur in Bunter at St. Avold, west of Saarbrücken.

Brown iron ore occurs in the Vosges-sandstone, and was formerly worked.

2.—MUSCHELKALK.—This is a marine deposit, and therefore calcareous. An abnormal condition is found in the lowest division, which is not calcareous but arenaceous, forming a sandstone with the organic remains of the Muschelkalk. It lies conformably to the Bunter, nearly horizontal and regular.

(c) Upper division (principal)		Nodosus limestone. Trochitæ limestone.
(b) Middle division	...	White argillaceous limestone. Clays with gypsum.
(a) Lower division	...	Dolomite, with Myophoria orbicularis — upper zone. Muschelsandstein—lower zone.

(*a*) LOWER MUSCHELKALK or (grès bigarré), formerly called Röth in neighbouring Bavaria, is 150 feet thick. The lower zone or Muschelsandstein has a dolomitic structure. Its sandstones give rise to better and more fruitful soil than those of the Vosges-sandstone, owing to its calcareous and argillaceous nature.

The *flora* is rare.

The *fauna* is rich, *ex.*: Monotis alberti; Mytilus eduliformis; Gervillia socialis, mytiloides, costata; Myophoria vulgaris, simplex, lævigata, ovata; Corbula incrassata; Myacites musculoides; Arca Schmidi; Tellina edentula; Terebratula vulgaris; Chemnitzia sp.; Turbonilla gracilis; Nautilus sp.; Goniatites Buchi; Encrinites liliiformis; Lima striata; L. lineata; Pecten lævigatus; Rhizocorallium Jenense.

The upper zone consists of grey, yellowish, and reddish strata of a dolomitic nature which predominates in the highest strata. It differs essentially from the lower zone in the presence of Myophoria orbicularis. Other fossils are found, such as M. ovata; Myacites; Rhizocorallium Jenense; and plant remains. They are, however, rarer than in the Muschelsandstein.

The upper and lower zones are distinct towards the north-west, but indistinct to the south and east.

(*b*) MIDDLE MUSCHELKALK is more developed in Bavaria, and contains gypsum at Ommersheim. The lower beds, consisting of red clays and loam, are used for brick manufacture. No fossils have been found.

(*c*) UPPER MUSCHELKALK.—It is essentially calcareous, as is seen from an analysis of the rock:—

$Si O_2$	2·62
$Al_2 O_3$	0·44
$Fe_2 O_3$	0·86
$Ca CO_3$	94·80
$Mg CO_3$	0·96
$H_2 O$	0·32
Trace of organic substance.	
	100

TROCHITÆ LIMESTONE.—This thick limestone is greyish white, has a conchoidal fracture, is often oolitic and glauconitic, full of Encrinites liliiformis; it is thirty feet thick, and contains siliceous concretions.

Fauna.—Lima striata; Terebratula vulgaris; Gervillia; Myophoria elegans and lævigata; Dentalium, etc.

Two specimens of Ammonites nodosus have also been found.

NODOSUS LIMESTONE or strata of Ammonites nodosus, is not much used; it has flinty concretions.

Fauna.—Lima striata; Terebratula; Gervillia socialis; Pecten lævigatus; Dentalium; Nothosaurus, etc.

PERMIAN.—As the depositions of the Permian followed directly upon that of the coal-measures it is not surprising to find it containing a few coal seams which, however, are far from possessing the thickness and importance of those of the true coal-measures. The clays and shales of the lower Rothliegende, as in true coal-measures, contain segregations of Sphærosiderite in such quantities that the latter are worked for iron.

These, as well as those of Ilfeld, to the south-west of the Harz, are the most important coal-bearing Permian strata. The Rothliegende is divided by Dr. E. Weiss into the (1) Upper R.; (2) Middle R., or strata of Lebach; (3) Lower R. or strata of Cusel. The two latter divisions he named Kohlenrothliegendes, from their possessing seams of coal. Herr von Dechen named the two latter divisions "Flötzleerer Kohlengebirg," from a mistaken idea of their identity.

(3) LOWER ROTHLIEGENDE, OR CUSEL STRATA.—The two limestone beds of Werschweiler, in which Callipteris conferta and Calamites gigas appear for the first time, are the lowest strata of this division. At other places these seams have no fossil remains, and towards the west become more indistinct, and the boundary is therefore less certain. In the subsequent strata is found a mixed Carboniferous and Permian flora, principally Callipteris conferta; silicified trunks of tree ferns; Walchia piniformis; Walchia filiciformis; Asterophyllites equisetiformis; (Sphenophyllum and Stigmaria, etc., are wanting). The flora being poor, the coal seams are rare, thin, and bad, from 8 to 10 inches thick. Animal remains, such as Amblypterus; Anthracosia; Estheria; Crustaceans; Rhabdolepis, and others, are found. The strata are partly sandstones (grey, red, brown,) fine and large grained conglomerates and arkose, red shales, etc.

Species passing from the coal-measures to the Cusel strata are—Odontopteris obtusiloba; Cyatheites arborescens, etc.

(2) MIDDLE ROTHLIEGENDE, OR LEBACH STRATA, consists of red shales and clays, slaty and fine grained sandstones, argillaceous limestones. The lowest stratum in this division is the only coal-seam, ·4 to ·8 feet thick, having a roof of siliceous limestone containing Acanthodes and Xenacanthus. Above this, and in some places taking its place, follow the ironstone segregations of Lebach enclosing in nodules the remains of Archegosaurus and Acanthodes.

Flora.—Odontopteris obtusiloba; Callipteris conferta; Calamites gigas and decoratus; Walchia piniformis and filiciformis.

Fauna. — Xenacanthus; Amblypterus; Rhabdolepis; Palæoniscus; Anthracosia; Estheria; Gampsonyx; as well as Archegosaurus and Acanthodes.

During the formation of this division there were eruptions of Melaphyre and quartz Porphyry. There is no remarkable difference between the flora and fauna of the Cusel and those of the Lebach strata, but certain forms, especially animal, belong exclusively to the strata of Lebach (Xenacanthus; Palæoniscus Vratislaviensis; Archegosaurus; Gampsonyx), in which the greater quantity of forms has been found.

(1) Upper Rothliegende. — The greater portion of it has been formed of fragments of Melaphyre and quartz Porphyry from the preceding divisions. It consists principally of conglomerates containing apparently no fossil remains except a fossil trunk found at Wadrill.

These sedimentary rocks are so intimately associated with the very numerous beds and dykes of the eruptive rocks that there can be no doubt of their having been formed simultaneously. Some beds of Melaphyre are remarkably regularly deposited, and have a thickness of from a few to seventy-five yards.

VII.—DESCRIPTION OF THE CARBONIFEROUS FORMATION.

The coal-measures of Saarbrücken correspond to the English coal-measures proper; older members of the formation, such as millstone grit or carboniferous limestone, have not yet been found.* It is matter of speculation as to what they rest on. The coal-measures have been divided for palæontological reasons into two divisions.

1st.—The Upper or Ottweiler Division, subdivided into—

(a) An upper zone.

(b) A lower zone { (1) upper beds containing no Leaia. (2) lower beds containing Leaia.

2nd.—The Lower or Saarbrücken Division.—These two divisions present petrographical as well as palæontological differences. The Saarbrücken rocks have a real carboniferous aspect; whilst the rocks of Ottweiler resemble more those of the lower Permian.

The following carboniferous plants have been found:—

Flora.—Sphenopteris irregularis, nummularia, cristata, delicatula, furcata; Cyatheites Bioti; Diplazites longifolius; Alethopteris muricata, pteroïdes, Pluckeneti; Annularia sphenophylloides; Sphenophyllum; Stigmaria ficoïdes; Sigillaria reniformis; Lepidophloios laricinus, with Lepidostrobus, etc.

* Professor Edward Hull, in a paper on the Classification of the Carboniferous series, read before the Geological Society, in 1877, considers the Coal-fields of Saarbrücken, Westphalia, and St. Etienne, as equivalent to the British Middle Coal-measures.

The following specimens which occur in younger strata, but so rarely that they may be considered as characteristically carboniferous, have also been found:—Cyatheites dentatus, Miltoni, unitus, oreopteroides; Alethopteris aquilina; Annularia longifolia.

The occurrence of Sphenophyllum saxifragefolium, Annularia sphenophylloides, and Odontopteris Schlotheimi and Reichiana in the Ottweiler strata, is one of the reasons of the separation of the latter rocks from those of Cusel.

(1) THE OTTWEILER DIVISION.—The lowest beds of this division consist of slates and shales; they are grey, from one to four inches thick, and contain numerous animal remains, of which Leaia Bäntschiana is the most important and characteristic, as its occurrence is restricted to them. These strata are unmistakeable, and have been traced with slight interruptions through the whole country between Hangard, and Bous on the Saar.

The next strata are sandstones, which are characterised by absence of Leaia. In this lower zone have been found: Anthracosia Goldfussiana; and Amblypterus; Rhabdolepis; Estheria tenella; Candona; Cyprides; fish scales and coprolites. Also an abundance of ferns; Pecopteris arborescens; Odontopteris obtusa; Neuropteris mirabilis; Cyatheites densifolius, elegans; Alethopteris truncata, Bredowi; siliceous trunks; Walchia rarely.

The upper zone consists principally of red sandstones; there is hardly any palæontological difference between it and the lower zone.

Coal is workable only in the lower zone; present, however, in both.

The strata dip, 5 to 10 degrees N.W.

(2) THE SAARBRÜCKEN DIVISION.—This division of the coal-measures contains nearly all the large and workable seams of coal.

The following plants have been found:—

Flora.—Neuropteris gigantea, heterophylla; Sphenopteris Höninghausii, obtusiloba, trifoliolata, acutiloba; Schizopteris anomala; Cyatheites pennœformis; Alethopteris lonchitica, erosa, nervosa; Dictyopteris neuropteroides, Brongniarti; Lonchopteris Defranci, Bauri; Calamites cannæformis, Cistii; Asterophyllum rigidus, longifolius; Nœggerathia; Annularia radiata; Cyclopteris orbicularis and lacerata; Odontopteris, etc. Also branches of Walchia pinniformis. Ferns in abundance.

The *fauna* is rare; the following have been found:—Anthracosia, Arthropleura armata; insects; crustaceans. Only one specimen of vertebrata: Anthracosaurus raniceps.

The strata consist of conglomerate (from 18 to 150 feet thick), sand-

stone, shale; a little limestone; no arkose. The roof of the seams generally consists of clay-slate; the thill invariably.

There are four distinct groups of strata, in which all the coal is found. They are separated from each other by non-coal-bearing strata. These groups are:—

1.—The Upper Group.
2.—The Upper Middle Group.
3.—The Lower Middle Group.
4.—The Lower Group.

They have not all been traced through the whole field, as it is a matter of some difficulty to identify them; in fact, to the east the three uppermost groups are represented only by one.

The Lower Group (Sections 5 and 6, pages 62 and 63) appears at the surface between Neunkirchen and Dudweiler, the strike of the strata being N.E. to S.W., and the dip 30 degrees to 45 degrees N.W. The mining operations of Dudweiler, Sulzbach, Altenwald, Heinitz, and König Collieries, as well as those of the Bavarian Colliery, St. Ingbert, are carried on in it. West of Dudweiler, beyond the great dyke, the strike of the seams becomes more north and south, with a westerly dip. This saddle-bend is accompanied by many faults, which converge fan-shaped towards the southern extremity of the great dyke, displacing the seams greatly. The bend is much clearer and more determined within the middle groups at some distance, for whilst N.E. of Tullenhaus the dip is N.W.; at Herrensohr and Jägersfreude the dip has assumed a westerly and south-westerly direction.

North-east, near Wellesweiler, the strata are bent towards the east in the form of a large saddle and accompanying trough, upon which follows a smaller mantle-shaped saddle. It has been impossible to trace these contortions in a south-western direction owing to the overlying Bunter.

Judging from the position of the strata, their dip and curvature at both extremities, there can be no doubt that they form the north-west declivity of a large anticlinal ridge, having a south-western to north-eastern direction, and that its south-eastern declivity ought to be found at no great distance below the Bunter. This, however, has not occurred.

No carboniferous strata dipping south-east are known between Neunkirchen and Dudweiler.

St. Ingbert is the only colliery in which the contact of the Bunter and the coal-measures has been explored. The Bunter, which generally has a very gentle dip to the south, has here a much greater dip.

A bore-hole, sunk by the Bavarian Government, near the entrance to the Rischbach Valley drift, passed through 664·4 feet of Bunter; then 17·4

feet of red and grey strata, so-called "Rothliegendes;" then through 815·8 feet of carboniferous strata, without finding a single seam of coal. Depth of bore-hole, 1497·6 feet.

The following are the results of two bore-holes laid down south of Dudweiler:—The first on the northern slope of Gückelsberg, passed through 228·8 feet of Bunter, and then through red and grey carboniferous strata, containing eight seams, the first of which was met with 179·7 feet below the Bunter. The bore-hole reached a depth of 769 feet. The second, at Stuhlsatzenhaus, only 3,706 feet south of Gückelsberg, gave a very different result. It passed through 1029·8 feet of Bunter; 65·6 feet of doubtful strata; and 439·0 feet of carboniferous strata, at which depth of 1534·4 feet the bore-hole was stopped without any coal-seams having been found. A line drawn through the two latter bore-holes passes northwards through Richard pit at Dudweiler colliery, and crosses the strike of the strata nearly at right angles.

The most justifiable conclusion to be derived from these facts is, that a great dyke passing parallel to the anticlinal ridge, between Gückelsberg and Stuhlsatzenhaus (nearer the former), has thrown the whole south-eastern portion of the anticlinal down to a great depth. This explanation derives great support from an examination of the conditions presented to us at Wellesweiler, where the great dyke which passes between the village and the colliery of that name would, if it were prolonged, pass between Gückelsberg and Stuhlsatzenhaus. Notwithstanding its thickness it has been impossible to trace this fault far, owing to the overlying Bunter. The lowest seams of this group are the so-called Rothhöller seams, which have not been worked at all in Prussia, and only to a small extent in Bavaria. Above them are 343 feet of non-coal bearing strata, and then follows the main portion of the group.

In the west, the lower group contains thirty-one workable and twenty-nine unworkable seams. By repeated separation of these seams into independent seams, and gradual appearance of new seams, they increase in the east to forty workable and seventy-seven unworkable seams.

The Blücher seam is a good example of this change. At Dudweiler it is 12 feet 9 inches thick, without any band; further east it becomes divided by a thin band. In the neighbourhood of Venitz Pit the band becomes thicker, and about 700 feet further east it is 55 feet thick, and the two portions form separate seams. Further east still, they subdivide into several seams. The principal seam retains, however, a thickness of from eight to nine feet. As shown by this example, the smaller bands increase in thickness towards the east, whilst the larger intervening strata increase to the west.

This shows the impossibility of making a general section for the whole lower group. The western and the eastern sections have only two corresponding seams—the clay seam No. 2 and the Blücher seam. The former is the characteristic seam of this group, as it has a constant clay band, and serves for the identification of seams when displaced by faults.

A bed of melaphyre, which crops out at Nauweilerhof, and is fou nd amongst the Rothhöller seams more to the east, is of service for the identification of seams at Dudweiler and St. Ingbert. (Fig. 2.)

Section in Level A at St. Ingbert Colliery.

Fig. 2.

M = melaphyre; C = coal-seam three inches thick; S = slate and sandstone; K = coal-seam 3·28 feet thick (seam No. 7 in Bavaria.)

This melaphyre is red and fine-grained; a few fragments of felspar and traces of a greenish black mineral (augite) are found in it. It is much decomposed. In level II. at St. Ingbert Colliery the bed of melaphyre appears in contact with seam 7. At one point it encloses a piece of coal, and the latter again a piece of melaphyre (Fig. 3). The

Section in II. Level at St. Ingbert Colliery.

Fig. 3.

melaphyre is highly decomposed and soft, is eight feet thick, and has concretions of a red substance. The coal is changed; when placed in the fire it breaks and simmers, and is worthless.

The seams which dip 30 to 35 degrees N. at Dudweiler form an anticlinal ridge below the Sulzbach Valley, the northern dip of which is

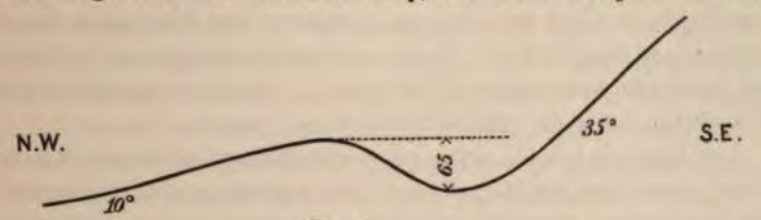


FIG. 4.

only from 10 to 15 degrees; the usual dip of the upper and middle groups. The distance between the top of the ridge and the bottom of the trough or synclinal is sixty-five feet. See Fig. 4.

This ridge decreases to the north-east but has been traced in the middle group, to the east of Friedrichsthal Colliery. Little is known about it to the south-west, owing to the presence of the large dyke west of Dudweiler.

The lower group is displaced by many faults. The apparently horizontal displacement of the seams is seen along the Blücher seam, which is represented on the map by a thick black line in the Saar drift level.

On the downthrow side of faults the seams often have remarkably thinner bands than on the upthrow side, so that on the downthrow side the total thickness of the strata is smaller than on the upthrow side. This is well exemplified by the Cerberus dyke and the large dyke west of Dudweiler.

The principal dykes and faults of the lower group, with their vertical height of throw, are—

1.—A large dyke west of Dudweiler Colliery, 343 to 378 feet.
2.—A fault east of Venitz Pit, along the Bavarian frontier, 206 feet.
3.—Cerberus dyke, which separates Sulzbach-Altenwald from Heinitz Colliery, 824 feet.
4.—Vampyre dyke, west of Heinitz Colliery, 274 to 343 feet.
5.—Minos dyke, 412 to 481 feet.
6.—Secundus dyke, west of König Colliery, forming the boundary between it and Heinitz Colliery, 480 to 548 feet.
7.—Styx dyke, east of König Colliery, 206 feet.
8.—The great dyke between König Colliery and Wellesweiler, about 1,000 feet.

The coal of this group is bituminous, mostly so in the lowest seams. Seams of less than 17·5 inches are considered unworkable.

The Rothhöller seams have not been tabulated in the east section, as they have not yet been explored in that direction.

The 29 unworkable seams in the west represent, together, 27 feet of

coal. The 77 seams in the east, 59·5 feet of coal. The total thickness of the lower group in the west, including the seams of coal, workable and unworkable, is 2,782 feet, and the relation of this thickness to that of workable coal is as 25·3 : 1. In the east the total thickness is 1,897 feet, and the relation to workable coal as 15·6 : 1. Therefore, the distribution of workable coal in the west to that in the east is as 1 : 1·6.

Clay ironstone is found in this group in the shape of large concretions in shales, pieces often weighing one ton. Some slates are much impregnated with iron pyrites ; they were worked for alum a long time ago, and called alum slates. The presence of pyrites at the outcrop of the Blücher seam caused a fire more than 100 years ago which is still smouldering downwards. The place of this fire is near Dudweiler, and is called "the burning mountain." It has caused changes in the neighbouring strata: clay slates have been partly changed into porcelain jasper of blue and red colour, and partly into hard red slates. The sight of this mountain was formerly much more striking than now, as the fire has retreated downwards, and only now and then sends up volumes of vapour.

The lower group is separated from the next upper group at Jaegersfreude by 1,098 feet of all but non-coal-bearing strata. They contain, namely, eight to nine seams of from 3 to 8 inches thickness. At Sulzbach-Altenwald, where the thickness is only about 549 feet, these small seams increase in number and thickness, but are insignificant.

Lower Middle Group (Section 4, page 59).—It emerges from under the Bunter, along the southern slope of the Sulzbach valley, forming a flat anticlinal between that valley and that of Fishbach. It is first displaced about 400 feet by the Hercules dyke, and immediately afterwards, about 200 feet, by a fault which runs nearly parallel to the strike of the strata. It then continues northwards as the Amelung group, and is thrown eastward by the Von der Heydt anticlinal towards the Friedrichsthal group, with which it is most probably identical. The workable seams of this group are shown in the section. The most important is the Hardenberg seam, which is probably the continuation of the Motz seam at Friedriechsthal. This will soon be ascertained by explorations. The Motz seam and some of the lower seams are affected by the Dudweiler anticlinal, described in the lower group.

The thick Kallenberg seam is regarded by some as the continuation of the Motz seam. It is, however, quite possible that the continuation of the Motz seam may be found lower down, corresponding to the seam recently opened out at Deidenkopf (which may have been called Kallenberg by mistake) and to a thick seam whose outcrop is exposed by the Heinitz railway cutting, and also to the lower seams of Ziehwald.

This group appears at Stangenmühle and Clarenthal in the form of a mantle-shaped saddle. It is the continuation of the Von der Heydt anticlinal stretching into Lorraine. The top of the saddle is removed, forming a so-called air saddle — the Clarenthal anticlinal. The lowest seams, however, form a complete vault. The Gross Rosseln group of seams, to which the Von der Heydt anticlinal reaches, belongs most probably also to this group, being surrounded by the upper middle group.

Besides the workable seams shown in the Section No. 4, this group contains twenty unworkable seams.

The coal of this, as of the upper groups, is non-bituminous; its total thickness is 2,304 feet, this being in relation to the total thickness of workable coal as 39·3 : 1. The seams have a dip of from 15 to 20 degrees.

Upper Middle Group (Section 3, page 59).—This group is separated from the Lower Middle by strata 560 to 980 feet thick, containing only from ten to twelve small seams 3 to 10 inches thick. These strata decrease in thickness eastwards, and are nearly lost at Friedrichsthal and Reden.

The group is 907 feet thick, or in relation to workable coal as 23 : 1. It has fifteen unworkable, and eleven workable seams, of which the principal is the Beust seam.

At Von der Heydt Colliery this group forms a flat saddle passing eastward; to the west of this colliery it is thrown up 175 feet by the Prometheus dyke and passes through Gerhard Colliery southward into Lorraine.

At Von der Heydt Colliery the Beust seam dips regularly to the north, but in the Burbach Valley, where it has a southern dip, it forms a synclinal trough. It is again raised into an anticlinal at Russhütte corresponding to that of Jaegersfreude. From Russhütte the group passes along the right bank of the Burbach stream by Prinz Wilhelm Colliery, the seams of which probably belong to this group, on to Gross Rosseln, Fürstenhausen Völklingen, back to Gerhard and Von der Heydt. The eastward prolongation of this group is not known. The Kallenberg seam, though quite different from the Beust seam, might be its continuation.

The intervening strata between the upper middle and the upper group are very irregular. At Gerhard Colliery they are about 1,373 feet thick, at Guichenbach and further east only a few feet, and at Völcklingen and Geislautern 549 feet. This irregularity is no doubt due to internal causes, the nature of which however is not yet known. No coal has been found in these strata.

Upper Group (Sections 1 and 2, pages 56 and 57).—Beginning at Geislautern, where it suddenly emerges from under the Bunter on the upthrow side of a large fault, this group passes by the collieries of

Hostenbach and Schwalbach, forming a flat anticlinal between them, along Rittenhofen, Guichenbach, and Dilsburg to Wahlschied. It is highly probable that this group continues eastwards to the Merchweiler and Reden collieries. The workings of Geislautern, Hostenbach, and Kronprinz collieries have exposed twelve separate workable seams, the lowest of which (seam No. 6) is worked at Geislautern.

At Guichenbach only six seams have as yet been opened out, the upper of which is 91 inches thick. This seam does not appear to be the continuation of the thick seam of Schwalbach; that continuation has to be looked for in some upper seam.

The identification of seams is particularly difficult in this group as their thickness often varies, and they are much disturbed.

The great similarity of the Knausholz and Schwalbach seams leads to the belief that they may be identical, and only displaced by the dyke east of Kronprinz Colliery, which in that case would have a vertical throw of 830 feet. Both these seams have a very constant band on which their identity is based. For a distance of about 1,200 feet square, the Schwalbach seam becomes divided into two portions, which become united outside this area. The greatest distance between the two portions of the seam is 15 feet.

The number of unworkable seams is twelve. The total thickness of the group is 2,798 feet, and the relation of the total thickness to the thickness of workable coal is as 58 to 1.

To the east of the field it has already been remarked there is only one group, the "Upper group," corresponding to the three uppermost groups in the west. In this group the collieries of Quierschied, Friedrichsthal, Merchweiler, Reden, and the day-level of Ziehwald, carry on their operations. The group contains forty-five workable and forty-three unworkable seams.

The total thickness of the group is 2,926 feet, that of workable coal 177 feet; or in the relation of 16·5 : 1.

If this group is compared with the three upper westerly groups there is first a thickness of—

Upper group (west)	2798·0 feet.
Upper middle group (west)	907·2 „
Lower middle group (west)	2304·2 „
Total	6009·4 feet.

Then a thickness of workable coal in—

Upper group (west)	47·5 feet.
Upper middle group	38·8 „
Lower middle group	58·6 „
Total	144·9 feet.

Therefore, the total thickness of the groups to the total thickness of workable coal is as 41 to 1. Consequently the eastern side of the field has the greater proportion of coal, as in the lower group.

The distribution of workable coal in the Upper group East is to that in the three Upper groups West as 2·6 to 1.

Groups and Intervening Strata.	WEST.							EAST.						
	Thickness including Coal Seams. Feet.	Workable Seams.		Unworkable Seams.		Total number of Seams.		Thickness including Coal Seams. Feet.	Workable Seams.		Unworkable Seams.		Total number of Seams.	
		Number.	Pure Coal in Feet.	Number.	Pure Coal in Feet.	Number.	Pure Coal in Feet.		Number.	Pure Coal in Feet.	Number.	Pure Coal in Feet.	Number.	Pure Coal in Feet.
Upper Group	2798·0	12	47·5	12	12·9	24	60·4	2926·0	45	177·4	43	30·9	88	208·3*
Intervening Strata ..	549·2	..	..	..	..	..	..							
Upper Middle Group	907·2	11	38·8	15	17·3	26	56·1							
Intervening Strata ..	961·1	..	..	..	..	..	..							
Lower Middle Group	2304·2	20	58·6	20	22·3	40	80·9							
Intervening Strata ..	1098·4	..	..	..	..	..	..	1029·7						
Lower Group	2782·3	31	110·1	29	27·2	60	137·3	1897·4	40	121·3	77	59·5	117	180·8†
Total	11400·4	74	255·0	76	79·7	150	334·7	5853·1	85	298·7	120	90·4	205	389·1

* Quality of coal.—Non-bituminous. † Bituminous.

Conclusions.—(1) From the table it appears that the coal-measures are twice as thick in the west as they are in the east.

(2) The lower group has nearly twice as many seams in the east as in the west, notwithstanding the omission of the Rothhöller seams in the east.

(3) The number of seams in the three uppermost groups in the west is ninety; that of the Upper group in the east eighty-eight. So that here, there is no increase of seams eastward as in the Lower group.

(4) Taking only the workable seams into consideration, the thickness of the coal in the west is to that in the east as 1 : 1·17, and the thickness of the non-bituminous coal only as 1 : 1·22.

(5) Taking the total number of seams into account, the thickness of bituminous coal in the west is to that in the east as 1 : 1·05.

According to calculations made some time since, based on the possibility of working to a depth of 3,430 feet, this coal-field would last, with a yearly output of 2,400,000 tons, about 3,000 years longer. As the output has, however, been more than doubled lately, the duration may be vaguely estimated at half that time, namely, 1,500 years.

VIII.—COAL.

The Saarbrücken coal is of pretty good quality; in the upper groups it is non-bituminous (sinterkohle), in the lower group bituminous (back-

kohle) and caking, though not to any very remarkable extent. In the middle groups the coal is mostly semi-bituminous.

The bituminous kinds are used for boilers, production of gas, and formation of coke.

The coals undergo great changes when exposed to the atmosphere. Even after a few days' exposure they yield less gas and less firm coke than coals which are fresh from the pit. Saar coals also produce much soot; they are very firm, giving a good percentage of large—

45 to 60 in the case of bituminous,

54 to 84 in the case of non-bituminous.

It has to be blasted. Backs occur at intervals at right angles to the dip.

The cleat of the coal is frequently accompanied by a thin film of dolomite, which sometimes increases much in thickness, and which gives the coal a peculiar appearance. This dolomite, which does not act injuriously on the coals, is composed of—

Carbonate of lime, CO Cao"	49·5
„ magnesia, CO Mgo"	48·7
Ferrous carbonate CO Feo"	1·6
	99·8

The amount of ash varies immensely; bituminous coal contains the least. Compared to other coals, the ash of the Saarbrücken coals contains very little lime and magnesia, which, considering the great amount of dolomite present in the cleat planes, is noteworthy.

CONSTITUTION OF ASH.

$Si\ O_2$	32·9
$Al_2\ O_3$	44·6
$Fe_2\ O_3$	18·2
Ca	1·5
Mg	1·7
	98·9

A peculiarity of the seams is the local increase of ash to such an extent as to make the coal valueless. This appearance is designated by the term "Versteinerung," or petrifaction. It is often associated with a decrease in the thickness of the seam, and with a disturbance in the deposition. The following are a few examples:—

Colliery.	Seam.
1.—Altenwald	No. 16.
2.—Gerhard	Heinrich.
3.—Kronprinz	Dilsburg.
4.—Prinz Wilhelm	Auerswald.
5.—Reden	Jacob.

	1.	2.	3.	4.	5.
Coal	69·72	60·32	40·35	79·07	21·93
Calcic carbonate	0·10	18·56	·40	10·42	49·82
Magnesic carbonate	0·19	10·27	1·04	6·09	17·32
Silicic anhydride	15·89	3·74	27·71	·49	1·90
Alumina and ferric oxide ...	10·28	6·54	22·55	3·30	8·59
Lime	...	·27	·31	·08	·36
Magnesia	·12	·02	·01	·05	...
Alkalies and loss	3·70	·28	7·63	·50	·08
	100	100	100	100	100

The specific weight of the bituminous coal is less than that of the non-bituminous. Average specific weight of all coals, 1·280.

COMPOSITION OF COALS.

Collieries.	Seams.	Percentage of					
		C.	H.	O.	N.	Ash.	
Duttweiler	Natzmer ...	83·36	5·19	9·06	·60	1·52	Bituminous.
	Beyer ...	81·29	5·30	8·54	...	4·87	
Heinitz ...	Blücher ...	80·53	5·06	11·91	...	2·50	
	Aster	78·97	5·10	13·22	...	2·71	
Gerhard ...	Beust... ...	72·38	4·46	15·05	...	8·11	Non-bituminous.
	Heinrich ...	70·20	4·70	13·27	...	11·83	
Von der Heydt	Carl 54" ...	70·30	3·52	18·14	...	8·04	
Reden ...	Kallenberg ...	71·52	4·06	14·79	...	9·63	
	Alexander ...	69·46	4·19	17·35	...	9·00	
Geislautern	Alvensleben ...	68·62	3·76	17·57	...	10·05	
	Emil	73·77	4·35	17·83	...	4·05	
Kronprinz ...	Schwalbach ...	62·90	3·84	17·14	...	15·86	

HEATING POWERS.

No.	Collieries.	Seams.	Lbs. of Water at 32° F. evaporated by 1lb of Coal.		*Lbs. of Water at 100° F evaporated by 1lb. of Coal.	
			First Experiment.	Second Experiment.	First Experiment.	Second Experiment.
			Lbs.	Lbs.	Lbs.	Lbs.
1	Gerhard ...	Beust ...	6·85	6·85	7·25	7·27
2	Do. ...	Heinrich ...	6·54	6·77	6·94	7·19
3	Heinitz ...	Blücher ...	7·92	7·74	8·40	8·22
4	Do. ...	Aster ...	7·61	7·85	8·08	8·33
5	Duttweiler...	Natzmer ...	7·54	8·07	8·00	8·57
6	Do. ...	Beyer ...	7·73	7·54	8·21	8·00

* Standard temperature taken by the English Government.

Blowers are often met with at Wellesweiler and Gerhard.

IX.—RED ROCK.

A few words must be said about a very curious occurrence, namely, that of the so-called "Rothe Gebirge" (Red Rock). It consists in a peculiar colouration of the coal-measures due to ferric oxide. Red spots appear first, which, increasing in number, soon colour the particular stratum intensely red. One stratum is generally affected at a time, the top and bottom strata being unaffected.

Seams of coal in the neighbourhood of red rock "petrify" and thin out; they become irregularly stratified, and faults occur.

X.—LOSS OF LIFE.

In relation to the output, loss of life in the Prussian part of the coal-field compares very favourably with that in the Westphalian coal-field.

Deaths in 1875 (resulting from Accidents).

Cause.	Saarbrücken.	Westphalia.
Firing shots (blasting)	3	16
Falls of stone and coal	24	78
Upon Inclines	2	46
In shafts	5	70
Upon Rolleyways	2	5
Vitiated air	8	21
By Machinery	1	9
Through Eruption of water ...	...	2
At bank	3	26
Other causes	1	6
	49	279

OUTPUT AND NUMBER OF MEN EMPLOYED IN 1875.

COAL-FIELD.	Collieries Worked.	Men Employed.	Output in Tons.
Prussian-Saarbrücken ...	14	22,608	4,497,804
Westphalia	259	81,822	16,434,790

The proportion of loss of life to output in tons is consequently, in :—

Prussian Saarbrücken ... ... as 1 : 91,792
Westphalia ... ... 1 : 58,906

The proportion of loss of life to number of men employed is, in—

Saarbrücken (Pr.) ... ... as 1 : 461
Westphalia ... ... 1 : 293

The loss of life so far as men employed is concerned is consequently less at Saarbrücken than in England, in which the proportion is as 1 : 436. Even the number of tons produced per life lost does not compare badly with that obtained in England, in which it is as 118,730 : 1.

XI.—OUTPUT.

TOTAL OUTPUT OF THE COAL FIELD IN 1876.

	Number of Collieries.	Number of Workmen.	Output.	
			Quantity in Tons.	Value in Pounds Sterling.
Prussian Government ...	9	22,771	4,397,186	2,130,996
Prussian Private ...	5	482	80,062	42,091
Bavarian	3	863	145,091	78,079
Lorraine	2	2,585	370,102	172,342
TOTAL	19	26,701	4,992,441	2,423,508

OUTPUT AT THE DIFFERENT GOVERNMENT COLLIERIES IN 1877 FOR THE FIRST HALF-YEAR.

	Tons.
1.—Kronprinz	118,708
2.—Gerhard	245,803
3.—Von der Heydt	187,849
4.—Dudweiler	279,275
5.—Sulzbach...	269,415
6.—Reden	297,965
7.—Heinitz	366,411
8.—König-Wellesweiler	195,457
9.—Friedrichsthal-Quierschied	106,664
Total for first half-year	2,067,547

XII.—WORK AND WAGES.

The Prussian portion of the coal-field being nearly wholly in the hands of the State, its management presents many peculiarities, especially in its relation to labour.

Nowhere is there so much done for the moral and material welfare of the men in the way of healthy houses, schools, societies for mutual benefit, and others.

Night and Sunday work has been removed as far as possible; the former ten to twelve hours day and night shifts, having been changed some time ago for two day shifts of eight hours each, though they are still sometimes extended to eleven hours.

There has, as yet, been no request for reducing the time; on the contrary the men employed on bargain work often try to prolong their shift against the advice of the officials.

Bargain work is enforced wherever it is feasible. About 90 per cent. of the men employed at the mines work by bargain.

Places are let every quarter. A price is fixed on each, and the men outbid each other by smaller offers.

The wages are regulated to a certain extent by the existing demand and supply of coal. They are altered at the Government mines in accordance with changes in the price of the necessaries of life without coercion on the part of the men.

Socialistic tendencies have not yet had any influence on the men; strikes are as yet unknown.

Until the year 1870 wages rose very gradually, but after the Franco-German war they rose in an unprecedented manner, owing to the sudden development of trade. This rise in wages attained its maximum towards the beginning of the year 1874, the wages being then 36 per cent. higher than in 1870. In the autumn of 1874, a slight retrogression took place, which continued all through 1875 and 1876. At the end of 1876 the wages had returned to what they were in the spring of 1872. This reduction in wages having taken place very gradually was not accompanied by distress.

The average wages in 1876 were 5¼ per cent. less than in 1875—15 per cent. more, however, than in 1870.

The following are the average wages for one shift of eight hours, after deducting all outlays, excepting lamp oil and new tools:—

WORK UNDERGROUND.

Year.	Piece Work. Hewing, Putting, and Stone work. 77 per cent. employed.	Mending Roads, Carpentering, Arching, Repairing, etc. 12 per cent. employed.
	s. d.	s. d.
1869.	2 7·2	2 2·3
1872.	3 2·6	2 7·2
1874.	3 7·4	2 11·0
1875.	3 3·9	2 10·0
1876.	3 1·5	2 9.0
1877.	3 0·7	2 8·0

The average yearly income of workmen engaged in the above occupations was, in—

	£	s.	d.
1869	35	4	3·4
1872	42	15	11·57
1874	46	10	4·25
1875	42	14	0·38
1876	40	0	10·76
1877	38	10	·11

The outlay on lamp oil and new tools has to be deducted. Lamp oil comes to 25s. yearly, being about a penny per shift; new tools about 9s. a-year.

The usual smiths' charges are already deducted in the above calculations, tools being sharpened by the collieries.

Taking these outlays into consideration the average yearly income of a workman in 1876 was £38 7s. 1d.; and deducting the compulsory subscription to the sick fund, namely, £2 0s. 6·9d., it amounted to £36 6s. 6d.

This is the average throughout, including putters as well as hewers; the former receive, however, smaller average wages and the latter much higher ones. In distributing sums earned by gangs of workmen the proportion allotted to a hewer is to that allotted to a putter, as 1 : $\frac{2}{3}$, or 1 : $\frac{3}{4}$, or some other fraction.

Hewers' wages per shift were:—

	s.	d.
1873	3	8·4
1874	3	10·14
1875	3	6·43
1876	3	3·9
1877	3	3·2

Being 7 to 8 per cent. higher than the total average.

By taking into account the wages of all workmen employed, both above and below ground, we get the following:—

TOTAL AVERAGE WAGES PER MAN PER SHIFT OF EIGHT HOURS.

	s.	d.
1871	2	9·5
1872	3	0·3
1873	3	3·8
1874	3	4·9
1875	3	2·6
1876	3	0·2
1877	2	11·0

XIII.—SCHOOLS.

Starting from the principle that the education of the working classes is of essential importance to the interest of the owners, the State, wherever acting as such, has greatly promoted it by—

(1) ELEMENTARY OR NATIONAL SCHOOLS.—In some cases defraying all expenses which otherwise would have to be incurred by the parish.

(2) SCHOOLS FOR FURTHER IMPROVEMENT.—For the purpose of consolidating the knowledge acquired in elementary schools. Of these there were, attached to the Government mines, in 1874, thirteen, comprising twenty-one separate classes and twenty-six masters.

	No. of Classes.	No. of Scholars.
Schwalbach ...	2	40
Luisenthal ...	3	140
v. d. Heydt ...	1	65
Dudweiler ...	2	70
Altenwald ...	1	25
Sulzbach ...	1	28
Kleinheiligenwald	3	106
Elversberg ...	1	34
Neunkirchen ...	1	43
Wellesweiler ...	1	29
Wiebelskirchen	2	60
Friedrichsthal ...	2	65
Quierschied ...	1	20
		725

Many of these scholars are over sixteen years of age.

Under the active management of the mining schools referred to below, the course of studies in these schools has been made to correspond with those taught there, so that scholars can pass readily from one to the other.

(3) LIBRARIES AND READING ROOMS for the further improvement of older as well as younger men. Lectures are also delivered in them by colliery officials.

(4) Associations of a Social and Musical Character.—Under this head comes a yearly festival, for which the State grants 3s. per man, this amounts to a sum of over £3,000. (See page 35.)

(5) A Weekly Paper, called the *Miner's Friend*, which combines instruction with entertainment.

(6) Sewing and Industrial Schools for the daughters of workmen. There were twelve of these schools at the collieries in 1876, and 282 girls received instruction. The cost of maintenance amounted to £450.

(7) Infant Schools.—There are eleven of these, attended by 1,300 children. Cost of maintenance, £588.

(8) Mining Schools.—(*a*) Preparatory Mining Schools (Steiger and Bergvorschule), of which there are three; one at Altenkessel, one at Dudweiler, and one at Neunkirchen.

(*b*) Principal Mining School (Hauptbergschule), of which there is only one, which is situated in Saarbrücken.

These schools supply all under-officials, such as deputies, overmen, and under-viewers, etc., and furnish a constant supply of educated as well as practical officials.

Scholars of Preparatory Schools have to keep themselves; they do not receive any money grant. The hours of work in school are—in summer, from 7 A.M. to 11 A.M.; and in winter, from 8 A.M. till 12 A.M.; the afternoon is reserved for underground labour. Each scholar makes a daily shift of six hours. Once a fortnight, on Saturday afternoons, they have two hours surveying. If not living at home a scholar spends from £1 16s. to £2 5s. for food and clothing monthly, whilst his average monthly wages come to from £2 10s. to £3. The course lasts a year and a half. Scholars of the Principal School have no time to earn their bread; they have to board either in Saarbrücken or in St. Johann. They receive a monthly allowance of £2 8s., and in a few cases extraordinary assistance. The hours of work are from 8 to 12, and from 2 to 4 every day.

A Surveyor's Class has been started since 1876 in connection with this school, so as to enable students to qualify for the Surveyors' State Examination. The surveying class takes up twelve hours weekly; Mondays and Tuesdays from 8 till 12, and Saturdays from 2 till 6; practical underground surveying takes up the rest of the time—on class days only four hours, and on other days eight hours. At the end of each course an examination takes place at each school.

The qualifications for entrance into Preparatory Schools are:—

(1) Not less than one year's underground experience.

(2) Conduct during that time must have been blameless.

(3) A certificate of attendance at the national school.
(4) A certificate of attendance at the schools for further improvement.
(5) A statement of occupation since leaving school and entering pit.
(6) A doctor's certificate as to perfect bodily fitness for mining duties.

The qualifications for entrance into the Principal School are :—

(1) Certificate of successful attendance at a Preparatory School, or possession of equivalent amount of knowledge.
(2) Certificate of work and good behaviour.
(3) Special certificate from the manager of the colliery at which he had been working as to practical capability.
(4) The candidate must have performed his military duties, or must be exempt from them.

Written statements must be handed in.

In 1876, 149 candidates went in for the entrance examinations at the Preparatory Schools; out of these only 59 entered. In 1877, the total number of scholars was 36, namely, 12 in each school. This diminution in numbers was owing to a raised standard of examination, requiring greater scientific knowledge and physical fitness, on account of the great number of old students waiting for situations. Twelve candidates were allowed to enter the Principal School. As an exception, several of these had not quite performed their military duties which were completed at the end of the course.

The surveying class, which began in 1876, commenced with two students, who were old scholars from the Principal School.

Of 71 students who attended the above schools in 1876–77—

18 were sons of under-officials.
24 „ of miners.
29 „ of non-miners.

The age on entering varied from seventeen to twenty-six.

The average time spent in underground labour before entering the schools was, in the case of the preparatory students two years and nine months, and five years and three months in that of the principal students. The time varied from one to six and a half years. 16 had performed military duties, 5 were exempt, 50 had still to serve, or were uncertain about it. Of these 71 students, two have died, and 69 have completed the course.

It has to be remarked that very few of these scholars carry on their studies when once started in life, and must necessarily forget most of what they have learned; the influence of the training, however, cannot be lost.

Each student, until he has got a situation, must every quarter produce a written composition. The theme, which is given by the authorities, relates as a rule to some underground subject. They are well looked over, and returned corrected with observations attached. In some cases they have to be re-worked. Although the one and a half year's course at the preparatory schools seems short, yet it does not seem advisable to extend it to two years. The small number of students makes the teaching very thorough, and allows of teaching in less time.

XIV.—THE YEARLY FESTIVAL.

Being at Saarbrücken at the time of the yearly festival, the writer availed himself of the opportunity of observing it at Von der Heydt Colliery. Each colliery entertains its own men. Small mortars were fired at intervals all the morning. At nine o'clock the miners began to assemble in their peculiar gala dress, resembling a uniform. At ten o'clock, headed by all the officials and accompanied by their bands, they marched to their different churches. After re-assembling, and this time accompanied by women and children, they proceeded in procession through the village, which was well decorated with flags, to the new well laid-out grounds of entertainment, which were also gorgeously decorated. Inscriptions, such as, "Welcome to the Happy Feast," "May Mining Prosper," and the old German salutation, "Glück auf," of which a translation is impossible, were to be seen.

The procession was here received and addressed by the manager, Herr von Ammon, whose guest the writer was. After the first toast had been proposed to their Emperor King, the people, to the number of 2,000, all sat down to tables and seats fixed in the ground, and partook of a copious repast, at which much beer was consumed, the bands playing meanwhile. After this, the younger members commenced dancing, the officials joined, and older men also indulged. There were whirligigs and other entertainments for children. At five o'clock the manager handed over silver watches to the five oldest miners in recognition of their faithful services. The feast came to a successful ending at seven o'clock.

This yearly re-union of officials and men is productive of much mutual good understanding. It helps to strengthen that bond of unity which should exist between employers and men.

XV.—DWELLINGS.

The settlement of the men at the Government Works is greatly promoted. For this purpose the colliery either (1) builds the cottages and lets them to the men; (2) builds the cottages and sells them to

picked men; (3) the men build their cottages and the colliery advances money, gives premiums and procures the site; or (4) the men build their cottages, and the colliery advances money without procuring a site.

The latter method has been mostly adopted, the first one is coming in vogue; it was first adopted during a sudden influx of men.

The money for premiums or advance is given partly by the State and partly by the Mutual Benefit Societies which are under State control. Advances amount to about £22 per cottage at 4 per cent. interest, 5s. to 6s. having to be paid back monthly. Colliery villages have also been started nearer the pits.

As the men did not take to these rows at first, inducements had to be held out, such as advance without interest and more premiums. But even then the colliery has had to build the houses and let them.

Large dormitories (Schlaffhäuser) have been erected at the largest collieries for the convenience of men living at a distance. The dormitory at Von der Heydt, which the writer inspected, presented more the appearance of barracks with room for 200 men; and the smartness, order, and cleanliness with which everything was carried on, cannot be too highly spoken of. These dormitories are supplied with extensive kitchen arrangements, meals being provided at very moderate prices. There are reading-rooms and sitting-rooms. These houses are much used by single men.

XVI.—NUMBER OF MEN EMPLOYED.

NUMBER OF MEN EMPLOYED AT THE DIFFERENT GOVERNMENT COLLIERIES DURING THE FIRST HALF-YEAR OF 1877.

1.—Kronprinz	1,677
2.—Gerhard	2,733
3.—v. d. Heydt	2,136
4.—Dudweiler	3,175
5.—Sulzbach	2,479
6.—Reden	2,749
7.—Heinitz	3,287
8.—König-Wellesweiler	2,030
9.—Friedrichsthal Quierschied	1,252
At the collieries	21,518
10.—Weighmen's Department	9
11.—At the Saarbrücken Canal Offices	127
	21.654
Horsekeepers	565
Total employed	22,219

Of these, 18,742 were employed underground and 3,519 at bank. Amongst the latter about 400 were between sixteen and eighteen years of age.

UNDER-OFFICIALS.

18 Under-viewers (Obersteiger).
13 Engineers (Maschinen werkmeister).
2 Coke and Gas Inspectors.
9 Foremen Masons (Bauwerk meister).
20 Overmen (Fahrsteiger).
37 Inspectors (at bank).
12 Engine and Smith Foremen.
202 Deputies (Grubensteiger).
35 Weighmen.
44 Colliery Watchmen.
14 Dormitory Keepers.
6 Roads Watchmen.

412 Officials.

Besides 58 Inspectors about the collieries.

Number of horses employed, about 600.

One-fifth of the men occupied dormitories.

The number of women and children was about 49,000.

XVII.—INDICTABLE CRIMES.

MINERS SENTENCED IN 1876 AND 1877.

	1876.	1877.
1.—For theft, fraud, etc.	53	26
2.—Immorality	4	14
3.—Murder	5	1
4.—Wounding and Assault	102	174
5.—Slander, false accusation	36	61
6.—Breaking Rules	20	19
7.—Disturbing the Peace, Misdemeanour	38	59
Total	258	354

NUMBER OF MEN SENTENCED PER 1,000.

In 1873	7·5
1874	9·0
1875	8·4
1876	11·1
1877	15·7

This increase is partly to be attributed to the greater enforcement of the law, and partly to a spirit of insubordination and dissatisfaction which has lately prevailed in the whole of Germany, greatly fomented by socialistic tendencies.

MINERS SENTENCED—TABULATED IN REGARD TO AGE.

	1876. Per 1,000.	1877. Per 1,000.
Under 20 years	11·1	12·4
From 20 to 25 „	15·0	30·1
„ 26 to 30 „	10·4	13·3
„ 31 to 40 „	7·6	8·5
Over 40 years	7·4	8·3

Showing that the younger, unmarried men are those who get most into trouble.

XVIII.—MODE OF WORKING.

For a long time the only method of working was by board and pillar (Pfeilerbau), of which three varieties are distinguished according to the direction in which the boards are driven—

1.—Fully to the rise ... ... (schwebend)
2.—Diagonally (or cross-cut ways) to the rise ... ... (diagonal)
3.—In a horizontal direction ... ... (streichend)

The direction in which the boards are driven is not necessitated by the preponderance of the cleat in one direction as it is in England; for the so-called "cleat" is unknown, and "backs" occur rarely.

LONGWALL (Strebbau) was first introduced in 1864, and has proved very satisfactory, enabling some seams to be worked which formerly were considered unworkable, and producing cleaner coals out of others.

As in board and pillar, so in long-wall, three varieties are distinguished according to the direction in which the face is advancing.

BOARD AND PILLAR.

1.—SCHWEBENDER PFEILERBAU.—Plate VI., Fig. 1, shows this variety of board and pillar as adopted in the Beust seam at Gerhard Colliery. The boards are driven to the rise with a breadth of 34 feet, leaving pillars 46 yards broad between them. The seam is over 12 feet thick, and has about 3 feet of bands. These are stowed away in the middle of the boards, thereby forming a travelling road on the right and an inclined plane on the left. As soon as the boundary is reached, lifts 9 to 11 yards in breadth are taken off. In this way half a pillar is worked off from each board by consecutive lifts.

2.—DIAGONALER PFEILERBAU.—Plate VI., Fig. 2, will explain this variety of board and pillar. It is very well developed at Saarbrücken, and invariably adopted in seams with a dip of not more than 13 inches in the yard, and not containing much gas.

The boards are started from the lower level with a breadth of 5 feet. At a distance of 25 feet from this level they assume a much greater breadth. Headways are driven for ventilation. The pillars are removed either in long slices parallel to the direction of the boards, or in short slices at right angles to the boards. The former method is employed when the roof is good and the seams not too thick; the latter in thick seams, and when the roof is bad.

The districts have to be kept as isolated from each other as possible because of the frequent occurrence of fires. Pillars A A are therefore left unperforated.

3.—Streichender Pfeilerbau.—Plate VII., which is a copy taken from the plan of the Blücher seam at Sulzbach Colliery, will explain this variety. The Blücher seam, which is from 10 to 12 feet thick, and contains no bands at this colliery, has an inclination of about 40 degrees. Levels have a vertical distance of 210 feet, one from the other. The portion of coal lying between two levels is worked from the lower level by driving boards and headways as in England. The block which is to be worked is made from 220 to 325 yards long. The upper blocks are worked first.

LONG-WALL.

1.—Schwebender Strebbau.—This is much employed. At the Gerhard Colliery the Carl and the Marie seams are worked by it. The Carl seam is 3 feet 1 inch thick, and contains no bands; the roof is bad and gas is rare. The Marie seam is 5 feet 3 inches thick, and has three bands, which amount to a thickness of 1 foot 2 inches. The inclination of both seams is 6 inches in the yard. Plate VIII. shows this variety, as seen in the Carl seam. It resembles the ordinary long-wall. The gob-roads, which are fitted up into inclined planes, are 82 feet apart. These are self-acting, the full tubs pulling up the empty tubs in their descent. There are four lines of rail. Two or three feet of roof are shot down in the gob-roads, and the stones so got are used for packing the walls. This is carefully done, and the remainder is thrown between the pack-walls; chocks are also used. The coal is blasted in the ordinary manner during the day, whilst packing and shooting down the roof is done by a night shift. The face of work was formerly kept entire and assumed a great length; the present step-like arrangement, with stalls twenty-seven yards long, distributes the pressure better. Two rows of props, alternately placed, are used to support the roof. The blocks do not exceed 140 yards in length. This variety of long-wall has produced a better ventilation and more round coal than board and pillar.

2.—Streichender Strebbau.—This variety of long-wall has been adopted in the Max seam at Gerhard Colliery. The Max seam has an

inclination of 14 inches in the yard, and gives out much gas, especially from the roof. Two roads are first driven to the rise, one of which becomes an inclined plane. From them the work is started in a horizontal direction, as shown in Plate IX. Gob-roads are left every 55 feet. Owing to a limited supply of stowing material the pack-walls are made 6 feet broad, and chocks are placed alternately behind them. The face assumes a step-like appearance, the upper stalls being started first. The upper breadth is kept a little ahead so as to allow the roof to settle on to the pack-walls before the lower breadth is started. The blocks do not exceed 140 yards in length. Pillars (A) of coal are left above and below to support the roads. Other varieties of long-wall have been tried in the Max seam, but none have answered so well as the one described. The inclined plane resembles that described by Mr. Galloway.* The frame is made to stop at different levels. It conveys only one tub at a time (10 cwts.), but is kept constantly going.

XIX.—SURVEYING.

Surveys are made by certificated surveyors, of which there are thirteen in this district. Certificated surveyors only may be employed.

Candidates for the surveyor's certificate have to pass an examination in the following subjects:—mathematics, geometry, mechanics, physics, geology, mining law, survey in all its branches, mathematical and physical geography, mining, mineralogy; and they must, in addition, make a large survey.

The places at which to qualify for this examination are the Mining Academies of Germany, of which there are several. The course extends over three years.

The law relative to underground surveying goes greatly into detail, much importance being attached to it for reasons of safety as well as economy.

The instruments employed for surveying are the theodolite, of which there are many kinds, the goniometer, and the dial.

The form of dial in use is what is called the "suspended dial" (Hänge compass). It consists of—

1.—The *dial* (compass, Fig. 1, Plate X.), which is divided into 360 degrees from right to left.

2.—The *frame* (Hängezeug, Fig. 2). It consists of an arc B and a circle C, at right angles to each other. The arc is one millemetre thick and fifteen millemetres broad. Hooks, A A, are for suspending the instrument to a string. The circle is half as

* Transactions, Vol. XXVII., page 174.

broad and twice as thick as the arc; it is joined to the arc as shown in Fig. 2; and is moveable around the axis E E, but only so far as the wings, F F, will allow. At D D, which are in line at right angles to E E, are two small projections which fit into corresponding depressions (A A, Fig. 1) in the dial; the latter are situated in the E.W. line. By this means the dial will assume a horizontal direction, at whatever angle the string may be drawn. This result would, of course, also be achieved if the circle was fixed to the arc.

The survey is made as follows :—A string is tightly fastened to props or any other pieces of wood, or even to the rock itself, by means of screws (Figs. 3 and 4). The distance between two screws ought not to exceed sixteen metres. By suspending the dial in the centre of the string, the bearing will be obtained. The vertical angle is then determined by suspending a plumbob (Fig. 5) to the string. Should the vertical angle be great, the instrument and plumbob are kept in their place by riders (Fig. 6). The string is measured by means of a light chain ten metres long, having five links to a metre; wooden riders (Fig. 7) are used for marking off lengths on the string. The vertical height, as well as the horizontal distance of each point, can in this way be very accurately ascertained.

Having made many surveys with this instrument, the writer has satisfied himself as to its suitability, and, in cases in which legs cannot be fixed, its superiority to other dial arrangements. Should ferruginous substances be present, any error arising from such a cause will be avoided by taking the bearing twice, once at each end of the string. Should the needle be deflected at the end of one length, the same deflection will take place at the beginning of the next length, and the difference between both readings will give the actual angle which one length of string makes with the other. Still greater exactness can be obtained by fixing the lengths of string as shown on plan in Fig. 8, where the dial is suspended on one length of string immediately below or above the preceding length. Whatever the deflection of the needle may be, the true angle formed by the two lengths will be ascertained.

Under the term "goniometer," is meant an instrument resembling a theodolite, but less cumbersome. The principle is almost the same as that of our "fixed needle" dial. It carries a telescope.

XX.—COST OF PRODUCTION AND PRICES.

The cost of production is high, averaging 6s. per ton. This must be due not only to the great difficulties encountered in working but also to a want of competition.

THE PRICES PER TON AT THE PIT MOUTH WERE IN MARCH, 1874, AT—

Colliery.	Best. s.	d.	Second Quality. s.	d.	Third Quality. s.	d.
Gerhard	22	0	18	4	9	2
v. d. Heydt	21	4	17	2	9	2
Reden	21	4	17	4	9	6
Dudweiler, Heinitz, Sulzbach, Altenwald, König	21	4	17	6	14	0

XXI.—COKE.

Although the coal is not particularly suitable for coking, the production of coke has lately much increased. Coking was first introduced in 1820, but has been carried on on a larger scale only since 1842.

The production was in—

	Tons.
1869	324,610
1870	231,905
1871	249,926
1872	364,126
1873	401,748

The half of this quantity is consumed in the coal-field itself at ironworks, etc.

The coke-ovens are rectangular; coal is introduced from above; and the coke forced out by rams. The coal has to be washed before it is fit for coking.

The coal-washing machine most in use is that of Siever and Co. The coal is first screened (gerätted), after which it is broken up (gewaltzt), and then passed through sieves of 4, 13, and 17 millimetres in diameter. Each portion is then washed separately; afterwards reunited, dried, and ground up (gemahlen) again; after which it is ready for the ovens.

The result of experiments at Dudweiler gives a percentage of coke of from 65 to 66.

XXII.—IRONWORKS.

There are thirteen ironworks, partly in Prussia and partly in Bavaria, which produce about 100,000 tons of pig iron per annum. The ores worked are:—Clay-ironstone, or sphärosiderite, which occurs in about a hundred different seams; then minette from Luxemburg and Lorraine, and hæmatite from the Lahn.

XXIII.—CONSUMPTION OF COAL IN THE COAL-FIELD ITSELF.

The home consumption is less in the Saarbrücken coal-field than in any other coal-field in Germany.

The home consumption in 1871 was in the—

	Per Cent.
Saarbrücken coal-field	27·4
Westphalian...	32·6
Waldenburg	33·5
Upper Silesia	52·6
Aix-la-Chapelle	63·9 of total production

The home consumption at Saarbrücken was in—

	Tons.
1860	431,634
1862	467,892
1865	574,138
1871	767,854

XXIV.—LIMITS OF EXPORTATION.

The Moselle and the Maine form the northern limit, beyond these rivers the Westphalian coal predominates. To the east, Schweinfurt, Nürenberg, and Munich, are the extreme points to which Saarbrücken coal reaches. At these points it has to compete with coal from Zwickau, Pilsen, Miesbach, and brown coal from Bohemia.

The southern limit extends very far owing to absence of coal in the Alps, in the southern part of Germany, and in the adjoining parts of France.

The greater part of the coal consumed by the Brenner railway, in 1871, was from Saarbrücken; so, also, the coal consumed in the Vorarlberg, at Chur, Glarus, Locle, Lausanne, and Geneva. There is no doubt that on completion of the St. Gothard railway, the Saarbrücken coal will find its way into upper Italy.

XXV.—AIR COMPRESSORS.

Though much has already appeared about these compressors in English papers, a passing notice cannot be withheld here. They are constructed on the principle adopted by Sommeiller, at the Mont Cenis tunnel, but with improvements of detail; and supply engines underground with compressed air.

The principle consists in preventing the heating of the air and avoiding a clearance space, by interposing a column of water between the piston and the air to be compressed. There are two or more of the compressors at nearly every colliery; they give good results.

XXVI.—SHAFTS.

The following Tables, and Plates XI., XII., XIII., and XIV., give a comprehensive view of all matters relative to the construction of the pit shafts of Saarbrücken. The shafts are enumerated, and whatever information could be obtained about them is appended:—

TABLE OF DATA RELATIVE TO THE VARIOUS PITS, WITH EXPLANATORY INFORMATION OF THE PIT SECTIONS.

I.—KRONPRINZ FRIEDRICH WILHELM AND GEISLAUTERN COLLIERIES—PLATE XI.

Name of Pit.	Depth from Surface in Feet.	Daily Output in Tons.	Description of Shaft.	Dks. p. Cage.	Tubs p. Deck.	Year in which begun.	Engines. Winding. Description.	Engines. Winding. H.P.	Engines. Pumping. Description.	Engines. Pumping. H.P.	Pumping Sets in the order in which they are placed in the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (if latter, what kind.)
Schwalbach— Pumping shaft	417 to V. level.	...	... ...	...	...	1826	.. ...	...	Beameng ...	75	Ensdorf level to II. level: 1. { Forcing s. { Lifting s. II. to V. level: 2.—Forcing ...	15 12 18	... ...	... ...* ... ...
Winding shaft	Do.	148	... ...	1	1	1826	... ...	75	... ...	...	... .	...	... ...	... ...
Griesborn— Railway shaft	620 to IX. level.	492	... ...	...	...	1857	Horizontal (dble.)	150	Beameng ...	350	From Surface to V. level:— 1.—Forcing... From V. to IX.: 2.—Forcing...	23 19	... ...	... ...† ... ...
Ensdorf— Winding shaft	556	...	... ...	...	...	1867	Do.	150	... ...	...	... ...	...	Conical	... ...‡
Schwalbach-Griesborn—														
Upcast shaft (1)	226	...	Dia. 5 ft. 7 in. = (1·72 m.)	...	...	1867	... ...	...	... ...	...	... ...	...	... ...	Guibal ‖
Do. (2)	164	...	Dia. 33 in.	...	...	...	... ...	...	... ...	...	... ...	...	... ...	Furnace§
Do. (3)	380	...	Dia. 6 ft. 7 in. (round)...	...	...	...	... ...	...	... .	...	... ...	...	... ...	Guibal ¶
Do. (4)	479	...	Do. do.	...	...	...	... ...	...	... ...	...	... ...	...	... ...	Do. ¶
Geislautern—														
Winding shaft	302	102	... ...	...	...	1838	Horizontal (dble.)	64	... .	...	... ...	...	... ...	... ...
Pumping shaft	302	..	... ...	...	...	...	... ...	...	... ...	75	... ...	...	... ...	... **
Upcast shaft	137	...	... ...	...	...	...	... ...	...	... .	...	... ...	...	... ...	Furnace ††

* The first deep shafts sunk—they are 52 feet apart; water is raised from V. level to Ensdorf day level (266 feet). † Finished in 1861; the engine winds from three levels—IX., VII. (469 feet), and V. (328 feet). ‡ Communicates with Griesborn shaft in IX. level. ‖ Ventilates all the western districts of colliery. § Ventilates all the eastern districts. ¶ In course of construction to replace shaft 2. ** Water is pumped from a depth of 282 feet. †† Sunk to seam VI.; the return enters at seam IV.

II.—GERHARD—PRINZ WILHELM COLLIERY.—PLATE XII.

Name of Pit.	Depth from Surface in Feet.	Daily Output in Tons.	Description of Shaft.	Dks. p. Cage.	Tubs p. Deck.	Year in which begun.	Engines.				Pumping Sets in the order in which they are placed in the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (if latter, what kind.)
							Winding.		Pumping.					
							Description.	H.P.	Description.	H.P.				
Josepha... ...	784 to V. level	...	Walled for a distance of 39 ft. from surface. The rest of the pit is timbered (rectangular frames supported by props).	...	...	1852	Powerful horizontal (dble.)	...	.. ..	...	... ...	...	... ...	... ...*
Hohberg ...	1,197 to V. level	...	Walled for a distance of 30 ft. from the surface. The rest is timbered.	...	...	1853	Small engine for consumption of engines.	...	Two engines	174 each	... ...	...	... ...	... ...†
Victoria at Pütt-lingen	922 to V. level	450	Walled for a distance of 390 ft. from surface; 10 inches to the bed. The rest of the pit is strengthened by 101 channel iron rings (one metre apart). To these are fixed the buntons and guides. Pulleys and frames for both engines of wrought iron.	...	...	1866	Horizontal (dble.) for larger division of shaft; a small engine winds from small division.	220	... ...	...	... ...	...	Conical	... ...‡
Gerhard—Upcast shaft	193	...	Elliptical; brick walling 16 inches in the bed.	...	...	1865	... ...	...	... ...	...	... ...	...	... ...	Guibal ‖
Albert at Louisenthal	703 to IV. level	460	Brick walling for a distance of 20 ft. from surface; 16 in. in the bed.	...	...	1862	Horizontal (dble.)	150	Beameng ...	143	... ...	...	... ...	... ...§
Albert East Pit	519	...	Brick walling for a distance of 108 ft. from surface; 1 ft. 8 in. in the bed. The rest is fitted up with channel iron rings like the Victoria pit.	...	...	1873	... ...	...	... ...	...	... ...	...	... ...	..... ¶

* Winds from Beust Seam; was sunk only to I. level in 1852; sinking was resumed in 1873 to V. level. † This celebrated shaft is the principal pumping shaft of Gerhard and Von der Heydt Collieries; water is raised from bottom to Veltheim drift (682 feet). ‡ This pit and the Richard pit are the first round pits which were sunk in this coal-field; sinking was completed in 1872. ‖ The division for ladders is boarded off the rest of the pit by planks strengthened with channel iron. § This pit was sunk to the III. level (499 feet) in eighteen months; sinking was completed in 1865. ¶ Principally for ventilation and travelling.

III.—VON DER HEYDT COLLIERY.—PLATE XII.

Name of Pit.	Depth from Surface. in Feet.	Daily Output in Tons.	Description of Shaft.	Dia. p. Cage.	Tubs p. Deck.	Year in which begun.	Engines. Winding. Description.	Winding. H.P.	Pumping. Description.	Pumping. H.P.	Pumping Sets in the order in which they are placed in the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (if latter, what kind.)
Krug Pit—No. 1	1,095	400	... ...	...	...	1854	Horizontal (dble.)	105	Small engine for feed water.	...	... ...	...	Flat for round wire rope.	... ...*
No. 2	1,092	...	... ...	...	...	1873	... ...	...	... ...	...	... ...	...	... ...	... ...†
Lampennest ...	150	...	... ...	...	...	1872	... ...	...	... ...	...	... ...	...	... ...	... ...‡
Kirschheck, No. 1	295	...	... ...	...	...	1856	... ...	...	... ...	...	... ...	...	... ...	... ...‖
No. 2	426 to I. level.	300	... ...	...	...	1859	Horizontl. (single)	50	Beam engine, one cylinder.	50	Forcing ...	12	... ...	... ...§

* A steam pipe conveys steam to the underground hauling engines; winds principally from Beust Seam; sinking was completed in 1865. † Winds from Beust and Upper Seams. ‡ Employed at present for lifting stones and water from staple in Beust Seam; will eventually be used for winding coal. ‖ Is being deepened to III. level of Amelung Seam; to wind and pump to Burbach day level. § The pit was sunk to Burbach day level in 1859, and was deepened to I. level in 1862.

IV.—DUDWEILER—JAEGERSFREUDE COLLIERY.—PLATE XIII.

Dudweiler—Gegenort shaft	1118 to IV. level.	300	Walled for a distance of 69 ft. from surface. The rest is timbered.	1	1	1843	Horizontal (dble.)	130	Woolf's principle. 2 cylinders condensation expansion.	260	Three forcing sets, one above the other.	19 each	Flat for round wire rope.	... ...*
Gegenort—Pumping shaft	1118 to IV. level.	...	Walled for a distance of 38 ft. from surface.	...	...	1851	... ...	...	There are 2 engines; each is single; has a beam working indirectly; condensation, expansion.	60 each	Each engine works:—			
											1.—Forcing ...	14	... ...	... ...†
											2.—Forcing ...	14	... ...	... ...
											3.—Forcing ...	12	... ...	... ...

* The water is raised to the Saar drift; coals are raised from III. level. † Originally intended for one engine; it was necessary to place another one in 1854; to this is due the insufficient space for winding; water is raised to Saar drift.

IV.—DUDWEILER—JAEGERSFREUDE COLLIERY.—CONTINUED.—PLATE XIII.

Name of Pit.	Depth from Surface in Feet.	Daily Output in Tons.	Description of Shaft.	Dks. p. Cage.	Tubs p. Deck.	Year in which begun.	Engines. Winding. Description.	Winding. H.P.	Pumping. Description.	Pumping. H.P.	Pumping Sets in the order in which they are placed in the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (if latter, what kind.)
Skalley—No. 1	1128 to IV. level.	150	Walled for a distance of 62 ft. from surface. The rest is timbered.	1	2	1849	1.—Beam engine for winding from I. level.	125	... ...	...	... ...	...	Conical for rd. wire rope.	... ...*
	...	70	... ...	...	...	...	2.—Hydraulic engine in III. level for drawing coals from IV. to III. level; latter has 2 hor. cyl. Spur-gearing.	4	... ...	...	... ...	...	Round.	... ...
No. 2	925 to III. level.	980 in 24 hours.	... ...	2	1	1850	Horizontal (dble.)	150	Direct acting for supply of feed & drinking water.	32	From Saar level (206 feet). Forcing sets	12 8	Conical for rd. iron rope.	... ...†
No. 3	925 to III. level.	980 per day from III. level	Walled for a distance of 125 ft. from surface. The rest is timbered.	2	2	1860 to Saar level.	Horizontal (dble.)	230	... ...	...	... ...	...	Conical for rd. steel rope.	.. ..‡
Richard ...	909 to II. level.	No regular output has yet been started.	Bricked for a distance of 203 ft., at which point there occurs a bed of conglomerate. In this bed the sides of the pit are unsupported for a distance of 7 ft. The arrangements shown in section then commence. Channel iron rings are placed at intervals of 1 met. Buntons are of oak.	...	...	1866	A temporary engine; winds with hemp rope.	30	... ...	...	... ...	...	... ...	

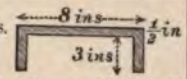
* Is situated close to the Saarbrücken main line of railway; coal is at present drawn from I. level (515 feet) by beam engine; and from IV. to III. level by hydraulic engine situated in latter, which works sixteen hours daily; ladders from III. level (925 feet) to IV. level only. † Situated 39 feet from above; winds from II. level principally, 718 feet; the head of water for engine of Pit 1 supplied from Saar level by pipes passing through travelling shaft of Pit 2. ‡ Pipes placed in travelling shaft convey compressed air to III. level for hauling engines; electric signals are used; the pit was deepened to III. level from 1867 to 1869.

IV.—DUDWEILER—JAEGERFREUDE COLLIERY.—CONTINUED.—PLATE XIII.

Name of Pit.	Depth from Surface in Feet.	Daily Output in Tons.	Description of Shaft.	Dia. p. Cage.	Tube p. Deck.	Year in which begun.	Engines.				Pumping Sets in the order in which they are placed n the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (if latter, what kind.)
							Winding.		Pumping.					
							Description.	H.P.	Description.	H.P.				
Camphausen— No. 1 No. 2	1856 including 52 ft. sump.	...	Bricked watertight for a distance of 98 ft., at which point a bed of conglomerate occurs. The rest is supported by channel iron rings, as shown in sections, with oak buntons. The rings are 1 metre apart.	...	...	1871	Temporary horizontal engines, with hemp ropes	50 30	... ...	...	... ...	...	... ...	... ...*
No. 3	558	...	... ...	...	...	...	... ...	...	... ...	...	... ...	...	... ...	... ...†
Jaegersfreude— Pumping shaft	551 to II. level.	...	Walled from surface to Saar drift (113 ft.).	...	...	1856	... ...	...	... ...	..	... ...	...	... ...	... ...‡
Winding shaft	551 to II. level.	...	Do.	...	...	1856	... ...	...	... ...	...	... .	...	... ..	... ...‖

* Situated in the Fischbach Valley; the permanent divisions will be as shown in section; temporary arrangements consist of small winding divisions with guides; and a segment in each pit, boarded off and communicating with a Zimmerman fan. † Also temporarily arranged, but will be walled and serve as upcast shaft; it winds coals from a thin seam 558 feet deep, for boilers, until Pits 1 and 2 supply themselves. ‡ 85 feet distant from winding shaft; is temporarily employed for winding, by means of an old beam engine of 8 horse-power; 25 tons daily output from I. level to Sulzbach drift (226 feet); the engine also raises water in boxes. ‖ Also temporarily fitted up; 40 tons daily are lifted from Saar to Sulzbach level by a 6 horse-power engine.

V.—SULZBACH—ALTENWALD COLLIERY.—PLATE XI.

Name of Pit.	Depth from Surface in Feet.	Daily Output in Tons.	Description of Shaft.	Dks. p. Cage.	Tubs p. Deck.	Year in which begun.	Engines. Winding. Description.	Engines. Winding. H.P.	Engines. Pumping. Description.	Engines. Pumping. H.P.	Pumping Sets in the order in which they are placed in the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (if latter, what kind.)
Mellin—No. 1 ...	981 to III. level	350 in 8 hours.	Walled 394 ft. from surface, the rest is timbered.	1	2	1853	Horizontal (dble.)	150	Ordinary beam engine.	120	Forcing ...	12	Conical for round iron rope	... ...
No. 2 ...	981	300 from III. level	Walled 66 feet from surface; the rest timbered. Above I. level the shaft has two divisions, both for winding. Below I. level there is a division for ladders.	1	2	1856	Old beam engine, with vertical cylinder.	80	... ...	...	... ...	...	Conical for round wire rope	... ...*
Venitz	879 to III. level	...	Timbered	...	...	1855	Vertical (single).	50	Ordinary beam engine (condensation).	120	Largest forcing set.	15	Flat ...	... ...†
Sulzbach–Upcast shaft	820 to III. level	...	Completely walled ...	...	...	...	... ...	...	... ...	...	... ...	...	... ...	Furnace in III. level.
The two Kreuzgräben Winding shafts	...	...	Water-tight brick walling 213 ft. (1·64 ft. to the bed) from the surface; then as above with channel iron rings. 	...	...	1872	Temporary at each pit.	30	Tangye's steam pump, underground.	...	... ...	...	... ...	... ...‡
Altenwald Railway—Pit No. 1	1,000 to III. level	800 and more.	Walled above Flottwell level.	1	2 ¶	1851	Horizontal (dble.) Diam. of cylin. 34in.; stroke 5ft.	150	... ...	...	... ...	...	Cast iron, conical. Breadth, 4 ft.; large diam. 17in.; small 13in.	... ...‖
No. 2	1,000 to III. level	540 and more.	Do. do.	1	2 ¶	1851	Do. do.	150	... ...	...	... ...	...	Conical. Brdth. 3ft., lrg. d. 17in. small 15in.	... ...§

* 46 feet distant from above. † The engine winds from II. to I level. ‡ Situated in the Fischbach Valley; not completed. ‖ 46 feet from Pit II.; winds only from I. level (610 feet) at present.
§ Winds from II. level (810 feet). ¶ @ 9 cwts. of coal.

V.—SULZBACH—ALTENWALD COLLIERY.—CONTINUED.—PLATE XI.

Name of Pit.	Depth from Surface in Feet.	Daily Output in Tons.	Description of Shaft.	Dia. p. Cage.	Tons p. Deck.	Year in which begun.	Engines. Winding. Description.	Winding. H.P.	Pumping. Description.	Pumping. H.P.	Pumping Sets in the order in which they are placed in the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (if latter, what kind.)
Gegenort Pit at Altenwald	918 to III. level	...	This pit has four divisions—two for winding, one for ladders (which also contains a pipe for compressed air and three sets of pipes for hydraulic pump); and a fourth division containing four pumping sets.	2	1	1853	Horizontal (dble.) Diam. of cylin., 28in.; stroke 5ft.	150	1.—Hydraulic pump (*see* Mr. Galloway's paper), which requires three sets of pipes.	...	... ...	...	Flat. Breadth, 3·28 ft.; diameter 14·5 in.	... ...*
									2.—Beam engine (condensation).	100	Four forcing.			
Upcast of Altenwald	...	...	Has a division for winding coals for boilers and for feed pipe.	...	...	...	... ...	...	... ...	...	... ...	...	... ...	2 Gnibals.
Upcast above 4th drift	...	...	... ...	...	...	...	... ...	...	... ...	...	... ...	...	... ...	Furnace at I. level. †
Upcast near Lochwiese	Has already reached I. level.	...	Water-tight walling for a distance of 295 ft. from surface; the rest is lined by rings of T iron, supported by oak props. Temporarily fitted up as shown by dotted lines. When this is removed the cages will have rope guides fastened, as in section, by screws. Walled canals will lead to ventilators. There will be two sets of doors to close opening at bank.	...	...	Being sunk.	... ...	...	... ...	...	... ...	...	... ...	... ...

* Sunk near the opening of Flottwell drift. † Is vertical as far as Saar drift, and communicates by means of an inclined drift built in masonry with I. level.

VI.—REDEN—MERSCHWEILER COLLIERY.—PLATE XIV.

Name of Pit.	Depth from Surface in Feet.	Daily Output in Tons.	Description of Shaft.	Dks. p. Cage.	Tubs p. Deck.	Year in which begun.	Engines.				Pumping Sets in the order in which they are placed in the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (if latter, what kind.)
							Winding.		Pumping.					
							Description.	H.P.	Description.	H.P.				
Reden—No. 1 ... Pumping shaft	282 to Saar drift.	...	Timbered	...	...	1847	... ...	...	Beam engine, single acting; diameter of cylinder, 7 ft.	300	One forcing ...	26	... ...	... ...
Reden—No. 2 ...	282	580	Walled to the Reden level. (98 ft.) From Reden level to Saar level (184 feet) timbered.	2	1	1850	Horizontal (dble.)	120	... ...	...	.. ..	...	Conical, round iron rope.	... ...
Do. No. 3 ...	479 to I. level.	760	Walled for a distance of 180 feet. The rest is timbered.	1	2	1862	Horizontal (dble.)	120	... ...	...	... ...	...	Flat for round iron rope.	... ...*
Pumping shaft at Klinkethal	423 to I. level.	...	Walled for a distance of 33 feet.	...	...	1854	... ...	...	Single and direct-acting.	70	Diameter of forcing sets	20	... ...	... ...
Principal Upcast at Dachswald	To the Saar level.	...	Is bricked from Saar level upwards for a distance of 69 feet, and is round. Upon this follows 98 feet of octagonal timbering; then walling to surface.	...	...	...	... ...	...	... ...	...	... ...	...	... ...	2 Guibals.†
Upcast at Heiligenwald	600 to I. level.	...	From I. level to Saar level octagonal timbering. From the Saar level the sides are unsupported for a distance of 148 ft.; the rest to surface is bricked, the section being round.	...	...	...	... .	...	... ...	...	... ...	...	... ...	2 Guibals.‡
Itzenplitz—No. 1	331 to Saar level.	580	Walled from surface to Reden level; timbered from latter to Saar level.	1	2	1860	Horizontal (dble.)	120	... ...	...	... ...	...	Flat for round iron rope.	... ...
Do. No. 2	138 to Reden level.	480	Timbered	1	1	1872	Vertical (Beam Engine).	16	... ...	...	... ...	...	Do.	... ...‖

* Principal winding shaft. † Ventilates eastern portion of Reden Colliery. ‡ Ventilates western portion of Reden Colliery. ‖ Coals are raised from Reden level.

VI.—REDEN—MERSCHWEILER COLLIERY.—CONTINUED.—PLATE IV.

Name of Pit.	Depth from Surface in Feet.	Daily Output in Tons.	Description of Shaft.	Dks. p. Cage.	Tubs p. Deck.	Year in which begun.	Engines. Winding. Description	Engines. Winding. H.P.	Engines. Pumping. Description.	Engines. Pumping. H.P.	Pumping Sets in the order in which they are placed in the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (if latter, what kind.)
Wildseiter's	761 to I. level.	...	Walled from surface for a distance of 20 ft. From here the division for the upcast alone is bricked; the divisions for winding and travelling are timbered.	...	..	1867	A temporary engine (double horizontal) winds coals and draws water.	30	... ...	...	... ...	...	... ...	... ...

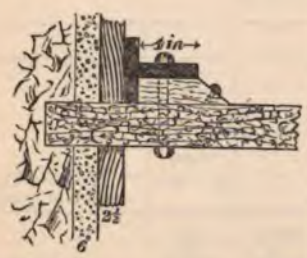
VII.—HEINITZ COLLIERY.—PLATE XIII.

Name of Pit.	Depth from Surface in Feet.	Daily Output in Tons.	Description of Shaft.	Dks. p. Cage.	Tubs p. Deck.	Year in which begun.	Engines. Winding. Description	Engines. Winding. H.P.	Engines. Pumping. Description.	Engines. Pumping. H.P.	Pumping Sets in the order in which they are placed in the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (if latter, what kind.)
Heinitz— No. 1	459 to I. level.	...	Bricked 1·12 feet in the bed from top to bottom. One of the divisions of the pit is for lowering materials, especially pumps.	...	...	1851	... ...	...	Cornish, direct and single acting.	300	1.—Forcing ... Column of water is 328 feet. 2.—Forcing ... Column is 180 feet.	29 29	... ...	... ...
No. 2	639 to II. level.	30	Timbered. Partly employed for lowering material.	1	2	1853	Horizontal single	45	... ...	...	... ...	...	Flat for round rope.	... ...*
No. 3	459 to I. level.	550 from Saar level.	Timbered	1	2	1855	1.—Beam engine winds from Saar level. 2.—Dble.; each cyl. 33 in. diam.; stroke, 6½ ft., and condensation; to wind from II. level.	125	Direct and single acting.	300	1.—Forcing ... 10 ft. stroke.	29	Flat for round rope.	... ...†

* Lies close to Pit I. † Situated 820 feet east of Pits I. and II.; coals are drawn during two 8-hours' shifts daily from the Saar level (271 feet).

VII.—HEINITZ COLLIERY.—CONTINUED.—PLATE XIII.

Name of Pit.	Depth from Surface in Feet.	Daily Output in Tons.	Description of Shaft.	Dks. p. Cage.	Tubs p. Deck.	Year in which begun.	Engines. Winding. Description.	Winding. H.P.	Engines. Pumping. Description.	Pumping. H.P.	Pumping Sets in the order in which they are placed in the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (if latter, what kind.)
Heinitz—*Cont.*—														
No. 4	459 to I. level.	1150 in 16 hours.	Walling, and peculiar shape from I. level to Flottwell level. Walling and section of Pit 2, from Flottwell level to bank. Pulley frame, is of iron. The pit top is covered by an iron roof.	2	2	1866	Double	150	... ...		... ...	..	Conical for rnd. rope.	... ...*
Upcast shaft ...	466 to I. level.	...	Completely bricked	...	...	...	... ...		... ...		... ...			Furnace in Saar level. Area of grate, 112 sq. ft.†
Dechen—No. 1...	426 to I. level.	...	Bricked 1·64 feet in the bed from top to bottom. A pipe for compressed air passes down the shaft	...	...	1854	Horizontal (double) only just put up.	150	.. ..		... ...		Conical, round rope.	... ...‡
No. 2...	426 to I. level.	950 from Saar level. 246 feet.	Walled from surface to 120 feet above Saar level. The rest is bricked.	2	2	1856	Horizontal (dble.)	150	... ...		... ...		Conical, round rope.	... ...‖
No. 3...	426 to I. level.	...	Walled from surface to Flottwell level, 59 ft. Buntons are fixed in walling. Below the level the buntons are fixed in the bare rock; on them rest rings of T iron, as shown in Plate . These rings consist of four pieces screwed together. Tubbing of 2½ in. planks is placed behind the T iron ring. A six-inch space between the tubbing and the wall of the shaft is filled up with concrete, consisting of two parts of Portland cement, three parts of slag, and three to four parts sand. This concrete is so firm that the rings and tubbing can safely be taken out. This has been done at some places in the pit. The elliptical form, 46 feet above and 20 feet below the Saar level, was necessary for pump arrangements. It has also been found necessary near the I. level.	...	...	1867	Horizontal (dble.)	32	1.—Woolf's indirect but double acting	150	1.—Forcing at Saar level ...	29	Conical, round rope.	... ...§
											2.—Forcing at I. level ...	15		
									2.—Ehrhard's indirect but double acting	150	1.—Forcing at Saar level ...	29		
											2.—Forcing at I. level ...	24		
											Iron spear rods.			



* Situated opposite Pit III.; the section of this pit was originally intended to be like that of Pit II., but having been started from the surface, and also from below upwards, the two excavations passed each other; and it was necessary to give it the shape shown in section. † The shaft is surmounted by a chimney 72 feet high; the smaller division was originally intended for ladders and pipes for compressed air; these having, however, been fixed in Heinrich Pit IV., the brick partition has now been partly removed. ‡ The shaft is fitted up with electric signals. ‖ Situated close to Pit I.; electric signals; there is a Sommeiller air compressor on the surface (forty horse-power). § Principal pumping shaft.

VII.—HEINITZ COLLIERY.—CONTINUED.—PLATE XIII.

Name of Pit.	Depth from Surface in Feet.	Daily Output in Tons.	Description of Shaft.	Dks. p. Cage.	Tubs p. Deck.	Year in which begun.	Engines. Winding. Description.	Winding. H.P.	Engines. Pumping. Description.	Pumping. H.P.	Pumping Sets in the order in which they are placed in the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (If latter, what kind.)
Dechen—*Cont.* Upcast	426 to I. level.	...	From Saar level upwards, for a distance of 66 ft., the shaft is lined, as shown in plan, with stone and bricks. There is an internal lining of fire brick for a distance of 39 ft. above Saar level, surrounded by an empty space. The brick lining ceases near the surface.	...	...	...	... ...	...	... ...	...	... ...	...	... ...	Furnace in Saar level at present; will be removed to I. level. Grate surface 100 sq. ft.*

* The shaft is surmounted by a chimney 62 feet high.

VIII.—KŒNIG—WELLESWEILER COLLIERY.—PLATE XIV.

Wilhelm—No. 1	400 to I. level.	450 in 10 hours.	Walled for a distance of 66 feet from surface.	1	2	1844	Horizontal (dble.)	130	... ...	..	... ...	..	Conical for round iron rope.	... ...*
No. 2	Do.	200	... ...	1	2	1854	Vertical	45	Beam engine (single).	75	Forcing sets ...	21	Flat for round iron rope.	... ...
No. 3	Do.	250	Walled for a distance of 66 feet from surface.	...	...	1870	Horizontal (dble.)	130	1.—Tangye's underground. 2.—Ommaney's underground.	... ...	Sets of pumps	9 and 11	Conical for round iron rope	... ...
Mehlphuhl ...	187 to Saar level.	...	The upper 89 ft. are fitted up with octagonal timbering; the lower 98 ft. with retanglr. timbering	...	...	1867	Horizontal (dble.) Is also used for pumping.	30	Tangye's underground.	...	Pumps... ...	6	Flat for flat hemp rope.	... ...
2 Upcast shafts	426	...	Walling from top to bottom.	...	...	...	... ...	...	... ...	...	... ...	...	... ...	Furnace in each.
Rhein-Nahe Railway Pit	494 to I. level.	150	Timbered	1	1	1867	Horizontal (dble.)	30	Single (direct-acting).	30	Pumps... ...	12	Flat for flat hemp rope.	.. ...†
Kohlwald ...	220	...	... ...	...	...	1869	... .	...	... ...	...	... ...	...	... ...	... ...‡
Wellesweiler—Gegenart	251	...	Timbered	...	...	1873	Horizontal (dble.) Is also used for pumping.	30	... ...	...	... ...	...	Conical for round rope.	... ...‖
Wellsw.—Upcast	154	...	Walled from top to bottom	...	...	...	... ...	...	... ...	...	... ...	...	... ...	Furnace.

* Principally for winding. † Near Neunkirchen. ‡ Temporarily abandoned. ‖ Will be deepened.

IX.—FRIEDRICHSTHAL—QUIERSCHIED COLLIERY.—PLATE XII.

Name of Pit.	Depth from Surface in Feet.	Daily Output in Tons.	Description of Shaft.	Dis. p. Cage.	Tubs p. Deck.	Year in which begun.	Engines. Winding. Description.	Engines. Winding. H.P.	Engines. Pumping. Description.	Engines. Pumping. H.P.	Pumping Sets in the order in which they are placed in the Shaft.	Int. Dia. of Pumps in Ins.	Description of Drum.	Furnace or Fan; (if latter, what kind.)
Friedrichsthal—Railway shaft..	426 to Saar level.	650 in 10 hours.	The upper 33 feet are bricked.	...	...	1857	Horizontal, double; winds from bottom to Grühling level.	120	1.—Direct acting at surface 2.—Woolf's, in Saar level ...	30 125	... ...	...	Flat for round rope (wire)	.. ...*
Erkershöhe ...	676	...	Walled for a distance of 292 feet from surface. Below this the shaft is lined by channel iron rings.	...	...	1872	Horizontal, double; 16 in. diam. of cyl., 3·3 feet stroke (temporary).	80	... ...	...	... ...	...	Flat for round rope	... ...
Friedrichsthal Hülfs	120	200 in 10 hours.	Walled from surface to a depth of 34 feet. The rest is timbered.	...	...	1872	Engine like at Erkershöhe	80	... ...	...	... ...	...	... ...	... ...
Tränkelbach—No. 1	...	...	Upper part is walled; the remainder fitted up with iron rings, iron buntons, and guides. The side cages in Pit II. will only have guides to one side.	...	...	1873	... ...		... ...	...	... ...	...	... ...	... ...
No. 2	...	...		...	...	1874								

* Near Eldstock tunnel; the tubs are taken out of Grühling level by an endless rope.

TOTAL THICKNESS OF STRATA IN THE UPPER GROUP—WEST.
SECTION 1.

Section at	Names of Seams and Nature of Intervening Strata.	Band. Ft.	In.	Fms.	Ft.	In.
Kronprinz Colliery.	Coal—Schwalbach Seam	1	3	1	3	4
	Sandstone and shale	.....		171	4	0
	Coal—Knansholz Seam	1	3	1	3	4
Hostenbach Colliery.	Sandstone and shale	.....		115	0	0
	Coal—Seam No. 1	2	7	1	0	5
	Sandstone and shale	.....		45	4	0
	Coal—Seam No. 2		9		3	4
	Shale, sandstone, and conglomerate	.....		20	4	0
	Coal—Otto Seam		6		2	4
	Shale and sandstone	.....		4	3	5
Geislautern Colliery.	Coal—Emil Seam	.....			1	9
	Shale and a bed of conglomerate	.....		22	5	1
	Coal—Seam No. 1 (Alvensleben, Pulverrauch)		8		4	10
	Shale	.....		1	0	11
	Coal—Seam No. 2	3	4	1	1	3
	Nature unknown	.....		51	3	0
	Coal—Seam No. 3		10		3	11
	Shale and sandstone	.....		11	2	6
	Coal—Bulow Seam, No. 4	2	1	1	1	0
	Shale and sandstone	.....		4	3	6
	Coal—Seam No. 5		2		2	5
	Shale and sandstone	.....		6	5	2
	Coal—Schneckmann Seam, No. 6	1	7		4	6
	Total	2	3	0	466	2	0
	Seams				10	2	5
	Band				2	3	0
	Coal				7	5	5

TOTAL THICKNESS OF STRATA IN THE UPPER GROUP—EAST.
SECTION 2.

Section at	Names of Seams and Nature of Intervening Strata.	Band. Ft.	In.	Fms.	Ft.	In.
Reden Colliery.	Coal	.....			2	2
	Shale and sandstone	.....		36	3	8
	Coal	.....			2	2
	Shale and sandstone	.....		8	0	1
	Coal	.....			1	9
	Shale and sandstone	.....		9	0	11
	Coal	.....		1	1	10
	Shale and sandstone	.....		22	5	4
	Coal—54 in. Seam	2	4	1	0	11
	Shale and sandstone	.....		9	0	1
	Carried forward	2	4	89	0	11

TOTAL THICKNESS OF STRATA IN THE UPPER GROUP—EAST.—CONTINUED.

SECTION 2.

SECTION AT	NAMES OF SEAMS AND NATURE OF INTERVENING STRATA.	BAND. Ft.	In.		Fms.	Ft.	In.
	Brought forward	2	4	...	89	0	11
	COAL—Upper portion of Heiligenwald Seam	1	0	...		5	9
	Shale	.....		...	1	0	10
	COAL—Lower portion of Heiligenwald Seam	2	2	...	1	5	5
	Thick bed of conglomerate	.....		...	22	5	4
	COAL—Alexander Seam III.	1	4	...		5	8
	Shale	.....		...	1	0	10
	COAL—Alexander Seam II.		9	...		5	6
	Shale	.....		...	1	0	10
	COAL—Alexander Seam I.	.....		...		3	0
	Shale	.....		...	1	0	10
	COAL—Alexander Main Seam	1	0	...	1	3	8
	Shale	.....		...	2	1	9
	COAL—Grubenwald Seam		10	...	1	0	10
	Shale	.....		...	4	3	6
	COAL	.....		...		1	8
	Shale	.....		...	8	0	1
	COAL	.....		...		1	6
	Shale	.....		...	1	0	10
	COAL—Alexander Seam		3	...		5	11
	Shale and sandstone	.....		...	17	1	0
REDEN COLLIERY.	COAL—Sophie Seam		3	...	1	2	7
	Shale	.....		...	1	0	10
	COAL—Jacob Seam	1	9	...	1	0	0
	Shale	.....		...	1	0	10
	COAL (very inferior at Reden)	3	2	...	2	3	5
	Shale	.....		...		3	5
	COAL	.....		...		1	9
	Shale	.....		...	1	0	0
	COAL—Leopold Seam		2	...		3	3
	Shale and sandstone	.....		...	6	5	2
	COAL	1	10	...		3	6
	Shale	.....		...	2	1	9
	COAL		5	...		2	7
	Shale	.....		...	1	0	10
	COAL		2	...		1	11
	Sandstone and shale	.....		...	8	0	1
	COAL—36 in. Seam	1	2	...		4	3
	Sandstone and shale	.....		...	8	0	1
	COAL		2	...		1	4
	Sandstone, shale, and a bed of conglomerate	.....		...	14	5	3
	COAL—35 in. Seam	1	10	...		4	10
	Sandstone, shale, and a bed of conglomerate	.....		...	16	0	1
	Carried forward	3	2	7	229	1	5

TOTAL THICKNESS OF STRATA IN THE UPPER GROUP—EAST.—CONTINUED.

SECTION 2.

Section at	Names of Seams and Nature of Intervening Strata.	Band. Fs. Ft. In.	Fms. Ft. In.
	Brought forward	3 2 7	229 1 5
Reden Colliery.	Coal	4	2 0
	Shale	.....	11 2 8
	Coal—37 in. Seam	1	3 3
	Shale	.....	2 1 9
	Coal	2 8	1 0 9
	Large fault in conglomerate	.....	17 1 0
	Coal	2 7	1 1 11
	Shale and sandstone	.....	2 1 9
	Coal	1 0	4 8
	Shale and sandstone	.....	22 5 4
	Coal—Kallenberg Seam	9	1 3 0
	Sandstone and conglomerate	.....	34 2 0
	Coal	4	2 1
	Shale and sandstone	.....	11 2 8
	Coal—Seam No. 9	1 0	4 0
	Shale and sandstone	.....	9 0 11
	Coal—Seam No. 8	6	4 0
	Shale and sandstone	.....	11 2 8
In Ziehwald Drift and Neighbourhood.	Coal—Seam No. 7	5	2 11
	Shale and sandstone	.....	5 4 4
	Coal—Seam No. 6	1 6	5 11
	Sandstone, shale, and conglomerate	.....	24 0 2
	Coal—Seam No. 5	1 0	2 11
	Sandstone and shale	.....	8 0 0
	Coal—Seam No. 4	1 0	3 0
	Sandstone, conglomerate, and shale	.....	11 2 8
	Coal—Seam No. 3	.....	4 1
	Sandstone and shale	.....	12 3 6
	Coal—Seam No. 2	11	5 6
	Sandstone and shale	.....	10 1 9
	Coal—Seam No. 1	6	2 10
	Shale and sandstone	.....	22 5 4
	Coal at Neunkirchen	.....	1 0 2
	Shale and sandstone	.....	20 3 7
	Coal at Neunkirchen	.....	2 7
	Shale and sandstone	.....	6 5 2
	Coal at Neunkirchen	.....	1 9
	Total	5 5 2	487 4 0
	Seams		35 2 6
	Band		5 5 2
	Coal		29 3 4

TOTAL THICKNESS OF STRATA IN THE UPPER MIDDLE GROUP—WEST.—SECTION 3.

Section at	Names of Seams and Nature of Intervening Strata.	Band. Ft.	In.	Fms.	Ft.	In.
Gerhard Colliery.	Coal—40 in. Seam				3	5
	Sandstone and shale			45	4	7
	Coal—23 in. Seam				1	11
	Sandstone and shale			6	5	2
	Coal—Heinrich Seam	3	0	1	0	5
	Sandstone and shale			3	2	7
	Coal—Carl Seam				3	1
	Shale and conglomerate			13	4	5
	Coal—Traugott Seam	2	11	1	1	7
	Shale, conglomerate, and sandstone			3	2	7
	Coal—Marie Seam	1	0		5	3
Von der Heydt Colliery.	Sandstone and conglomerate			6	5	3
	Coal				1	9
	Sandstone and conglomerate			3	2	7
	Coal		8		2	9
	Sandstone and conglomerate			14	5	3
	Coal				1	9
	Sandstone and conglomerate			16	0	1
	Coal—Beust Seam	2	9	2	0	3
	Sandstone, conglomerate, and shale			28	3	7
	Coal—Constanze Seam		3		3	0
	Total	1	4 7	151	1	3
	Seams			8	1	2
	Band			1	4	7
	Coal			6	2	7

TOTAL THICKNESS OF STRATA IN THE LOWER MIDDLE GROUP—WEST.—SECTION 4.

Section at	Names of Seams and Nature of Intervening Strata.	Band. Ft.	In.	Fms.	Ft.	In.
In Saar Drift.	Coal—Upper Hardenberg Seam		6		3	5
	Shale				2	1
	Coal—Lower Hardenberg Seam	1	6	1	1	10
	Shale			4	3	6
	Coal—Charlotte Seam		8		4	6
	Sandstone, containing pyrites			17	1	0
	Carried forward	2	8	24	4	4

TOTAL THICKNESS OF STRATA IN THE LOWER MIDDLE GROUP—EAST.—CONTINUED.—SECTION 4.

Section at	Names of Seams and Nature of Intervening Strata.	Band. Ft. In.	Fms. Ft. In.
	Brought forward	2 8	24 4 4
Jaegersfreude Colliery.	Coal	2 2	1 0 0
	...	.....	3 2 7
	Coal—Seam No. 3	.....	2 3
	Shale	.....	1 0 10
	Coal	.....	2 2
	Sandstone	.....	6 5 2
	Coal—Seam No 4	6	3 9
	Sandstone and shale	.....	10 1 10
	Coal	.....	2 4
	Sandstone and shale	.....	20 3 7
	Coal	3	3 5
	Sandstone and shale	.....	19 2 9
	Coal	1 0	3 1
	Sandstone and shale	.....	9 0 11
	Coal	3	2 4
	Sandstone and shale	.....	6 5 2
	Coal	1	2 1
	Sandstone and shale	.....	6 5 2
	Coal	.....	2 1
	Sandstone	.....	10 1 10
	Coal	1 8	4 5
	Sandstone and shale	.....	3 2 7
	Coal—Seam No. 5	2 4	1 0 7
	Sandstone and shale	.....	5 4 4
	Coal	6	2 3
	Sandstone and shale	.....	5 4 4
	Coal—Seam No. 6	1	2 9
	Sandstone and shale, enclosing a bed of conglomerate	.....	91 3 4
	Coal	.....	3 9
	Sandstone and shale, enclosing two beds of conglomerate	.....	57 1 4
	Coal—Seam No. 2 of Altenwald	.....	2 10
	Sandstone and shale, enclosing a bed of conglomerate	.....	91 3 4
	Coal (in Saar Drift)—Seam No. 1 of Altenwald	4	2 8
	Total	1 5 10	384 0 2
	Seams		11 4 6
	Band		1 5 10
	Coal		9 4 8

TOTAL THICKNESS OF STRATA IN THE LOWER GROUP—EAST.

SECTION 5.

Section at	Names of Seams and Nature of Intervening Strata.	Band. Ft.	In.		Fms.	Ft.	In.
Heinitz Colliery.	Coal	1	0			2	11
	Shale, sandstone, and conglomerate	.....			27	2	11
	Coal	1				1	10
	Shale	.....			6	5	3
	Coal	1				1	7
	Shale	.....			1	0	10
	Coal	2				1	10
	Shale	.....			10	1	10
	Coal	7				2	4
	Sandstone and conglomerate	.....			5	0	11
	Coal—Stohlberg Seam	1	2			3	10
	Shale	.....				3	5
	Coal—Thiele Seam	2	11		1	0	10
	Shale	.....			1	0	10
	Coal—August Seam	2				4	10
	Shale	.....			2	1	9
	Coal—Borstel Seam	1				4	8
	Conglomerate, sandstone, and shale	.....			6	5	3
	Coal—Waldemar Seam	1	1		1	0	8
	Shale	.....			1	0	10
	Coal	.....				1	9
	Shale	.....			3	2	7
	Coal—Wrangel Seam	11				5	0
	Conglomerate, sandstone, and shale	.....			6	5	3
	Coal	.....				1	8
	Shale	.....			1	0	10
	Coal	1	1			3	4
	Shale and sandstone	.....			3	2	7
	Coal—Nostitz Seam	1				3	7
	Shale and sandstone	.....			4	3	6
	Coal	.....				1	5
	Shale and sandstone	.....			4	3	6
	Coal—Grollman Seam	1	3			3	8
	Shale	.....			1	0	10
	Coal—Gneisenau Seam	1	1		1	1	8
	Shale and sandstone	.....			3	2	7
	Coal—Upper Thielemann Seam	.....				3	2
	Shale and sandstone	.....			3	2	7
	Coal—Lower Thielemann Seam	.....				2	2
	Shale and sandstone	.....			3	2	7
	Coal—Braun Seam	3				3	8
	Shale, sandstone, and conglomerate	.....			10	2	0
	Carried forward	2	0	0	121	1	1

TOTAL THICKNESS OF STRATA IN THE LOWER GROUP—EAST.

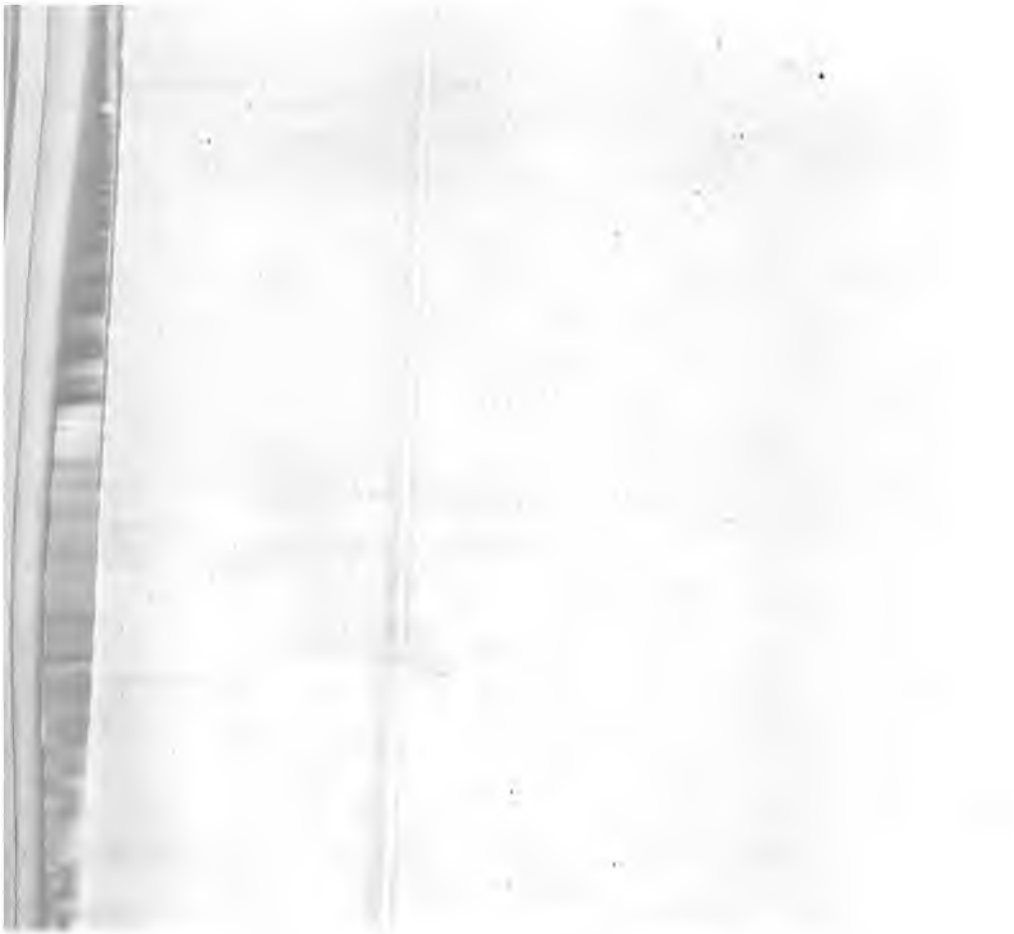
CONTINUED.—SECTION 5.

SECTION AT	NAMES OF SEAMS AND NATURE OF INTERVENING STRATA.	BAND. Fs.	Ft.	In.	Fms.	Ft.	In.
	Brought forward	2	0	0	121	1	1
HEINITZ COLLIERY.	COAL—Clay Seam, clay 1 ft. 4 in.		3	1	1	1	11
	Shale				1	0	10
	COAL—Bonin Seam					2	2
	Shale				2	1	9
	COAL—Aster Seam		11		1	0	8
	Shale				2	1	9
	COAL—Rauch Seam		1	0		5	0
	Shale and sandstone				9	1	0
	COAL—Blucher Seam		9		1	3	7
	Shale				1	0	10
	COAL					1	10
	Shale and sandstone				3	2	7
	COAL—Tauenzien Seam		7			4	4
	Shale				1	0	10
	COAL					1	7
	Shale and sandstone				14	5	4
	COAL—Scharnhorst Seam		5			5	1
	Shale and conglomerate				13	4	5
	COAL		1	2		3	5
	Sandstone and shale				2	1	9
	COAL					1	9
	Sandstone and shale				32	0	4
	COAL		1	6		4	6
	Sandstone and shale				18	2	0
	COAL					2	0
	Sandstone and shale				12	3	7
	COAL					1	5
	Vampyre Dyke				18	2	0
	COAL					1	7
	Shale				1	0	10
	COAL—33 in. Seam		1	1		3	7
	Shale				2	1	9
	COAL		1	0		3	3
	Sandstone and conglomerate				35	3	0
	COAL			6		2	2
	Shale and sandstone				11	2	8
	COAL—36 in. Seam			3		3	4
	Total	4	0	3	316	1	6
	Seams				24	1	7
	Band				4	0	3
	COAL				20	1	4

TOTAL THICKNESS OF STRATA IN THE LOWER GROUP.—WEST.

SECTION 6.

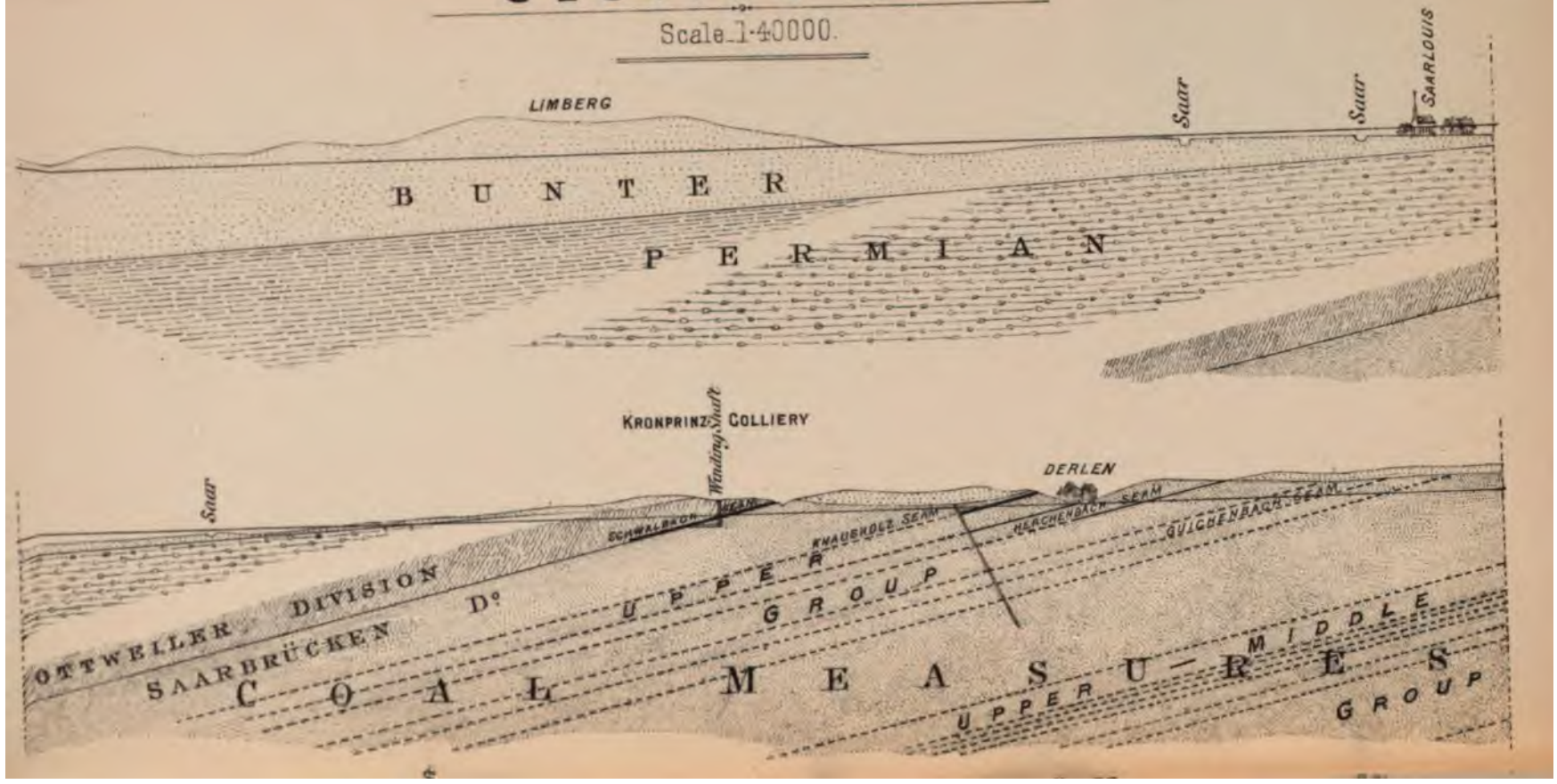
Section at	Names of Seams and Nature of Intervening Strata.	Band. Ft. In.	Fms. Ft. In.
Dudweiler Colliery.	Coal—Seam No. 1	6 ...	3 0
	Shale	....	2 1 9
	Coal—Seam No. 2	4 ...	2 3
	Shale	....	5 4 4
	Coal—Seam No. 3	5 ...	5 1
	Conglomerate	....	9 1 0
	Coal—Seam No. 4	8 ...	4 6
	Sandstone, including 12 ft. of conglomerate	....	11 2 8
	Coal—Seam No. 5	....	2 2
	Sandstone	....	17 1 0
	Coal—Boyen Seam, No. 6	2 9 ...	1 4 7
	Shale	....	2 1 9
	Coal—Seam No. 7	5 ...	4 4
	Shale	....	2 5 2
	Coal—24 in. Seam	....	2 3
	Shale	....	2 5 2
	Coal—18 in. Seam	....	1 6
	Shale	....	5 4 4
	Coal—Beyer Seam, No. 8	4 ...	2 11
	Sandstone, including 12 ft. of conglomerate	....	24 0 3
	Coal—Müffling Seam, No. 10	3 0 ...	1 5 5
	Shale	....	3 0 7
	Coal—Pfuel or Clay Seam, No. 11 (Clay 2 ft. 7 in.)	2 9 ...	1 1 9
	Sandstone, including 34 ft. of conglomerate	....	20 3 8
	Coal—Blücher Seam, No. 13	....	2 0 10
	Sandstone and shale	....	5 4 4
	Coal—Seam No. 14	2 ...	4 7
	Sandstone and shale	....	29 4 7
	Coal—Kleist-Nollendorf Seam, No. 15 ...	....	2 2
	Sandstone and shale	....	6 5 3
	Coal—Dennewitz Seam, No. 16	....	4 1
	Sandstone and shale	....	8 0 1
	Coal—York Seam, No. 17	2 1 ...	1 0 5
	Sandstone and shale	....	32 0 4
	Coal—27 in. Seam	....	2 4
	Sandstone and shale	....	5 4 4
	Coal—Natzmer Seam	1 0 ...	2 9
	Sandstone and shale	....	8 0 1
	Carried forward	2 2 5	218 5 7

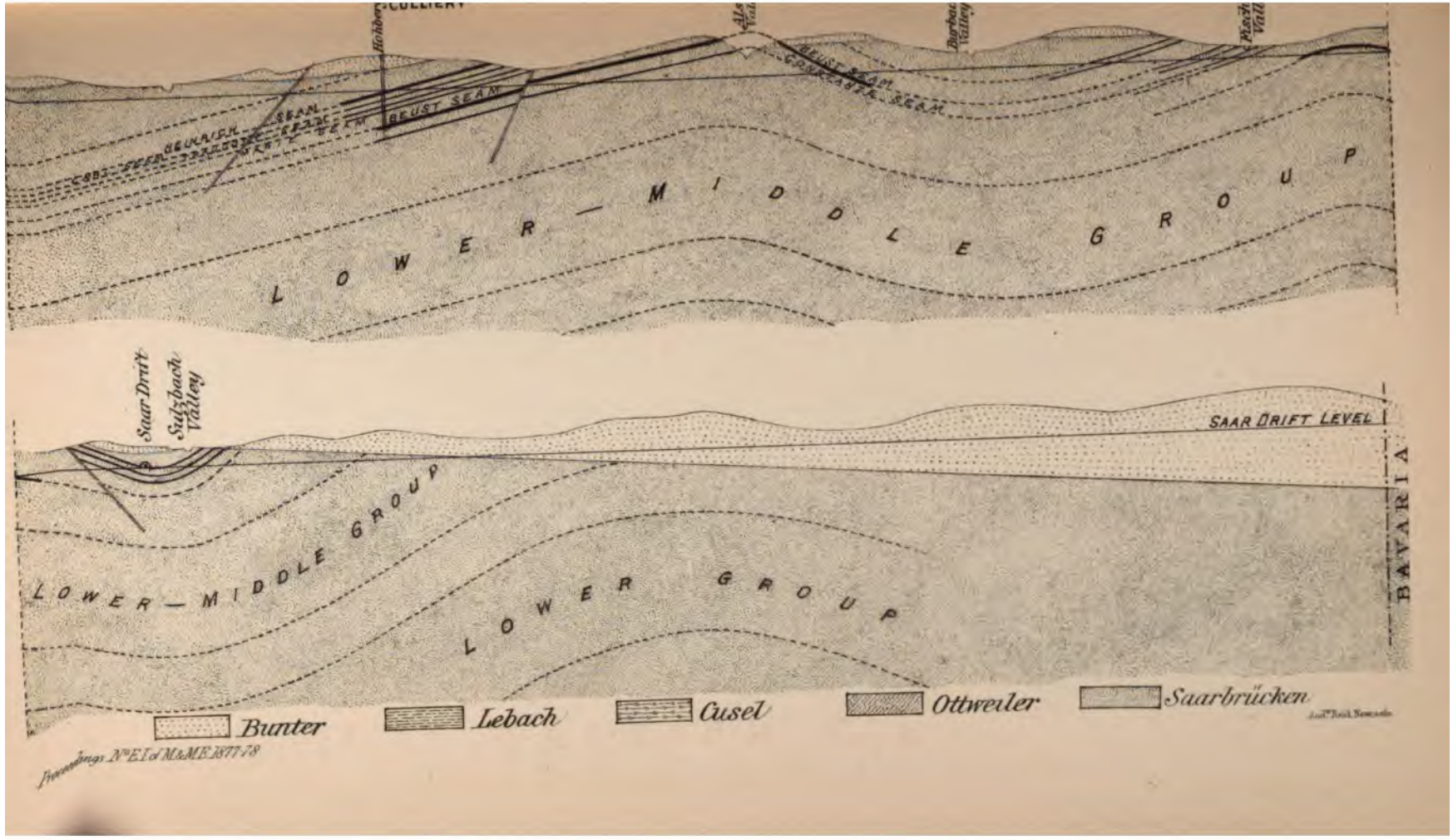


To illustrate Mr. A. R. Sawyer's paper "On Mining at Saarbrücken."

SECTION E. F.

Scale 1:40000.




COLLIERY
BEUST SEAM
LOWER — MIDDLE GROUP
Saar Drift
Sulzbach Valley
SAAR DRIFT LEVEL
BAVARIA
LOWER — MIDDLE GROUP
LOWER GROUP
Bunter
Lebach
Cusel
Ottweiler
Saarbrücken
Proceedings N°E.I of M&ME 1877-78

To illustrate Mr. A. R. Sawyer's paper on "Mining at Saarbrücken"

TABLE OF ENGLISH EQUIVALENTS TO GERMAN TERMS EMPLOYED AND REFERENCE TO SECTIONS.

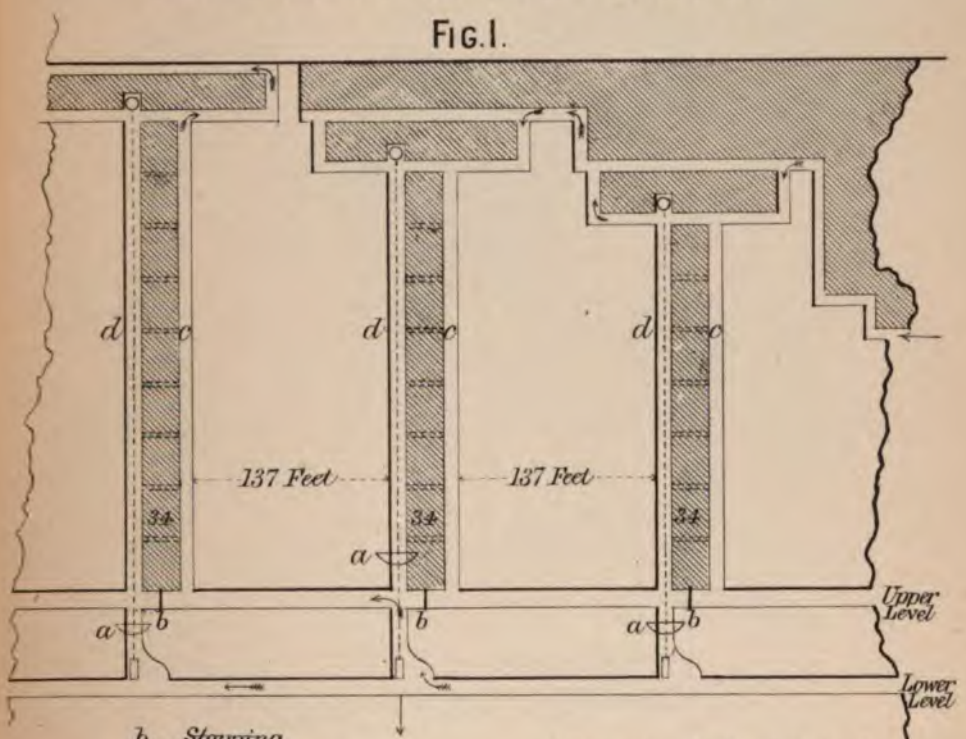
Formations	German Subdivisions			English Equivalents
Triassic	Keuper		Insignificant here	Keuper
	Muschelkalk	Upper	Nodosus Limestone Trochita Limestone	(Wanting)
		Middle	White Argillac. Limestone Clays with Gypsum	
		Lower	Upper Zone Dolomite containing Myophoria orbicularis Lower Zone Muschelsandstein	
	Bunter-Sandstein	Upper	Voltzia Sandstein	Bunter
		Lower	Vosges Sandstein	
Permian			1. Scarcely represented in Germany	Upper Red Sandstone and Marls
	Zechstein		Zechstein and Kupferschiefer	Magnesian Limes and Marlslates
	Rothliegendes	Upper	Upper-Member	Lower Red Sandstones and Marls
		Middle	Lebach	
		Lower	Cusel Kohlen-Rothliegendes Coal Measures contain few coal seams (Dechen)	
Carboniferous	Productive Kohlen-Formation	Upper or Ottweiler Division	(1) Upper Group (2) Lower Group (1) Without Leaia (2) With Leaia	Coal Measures in their restricted sense
		Lower or Saarbrücken Division	(1) Upper Group (2) Middle do. (3) Lower do.	
			Flötzleerer Sandstein	Millstone Grit

Inst. Mech. Engineers

To illustrate Mr. A. R. Sawyer's paper "On Mining at Saarbrucken"

Board and Pillar (First Variety.)

Fig. 1.

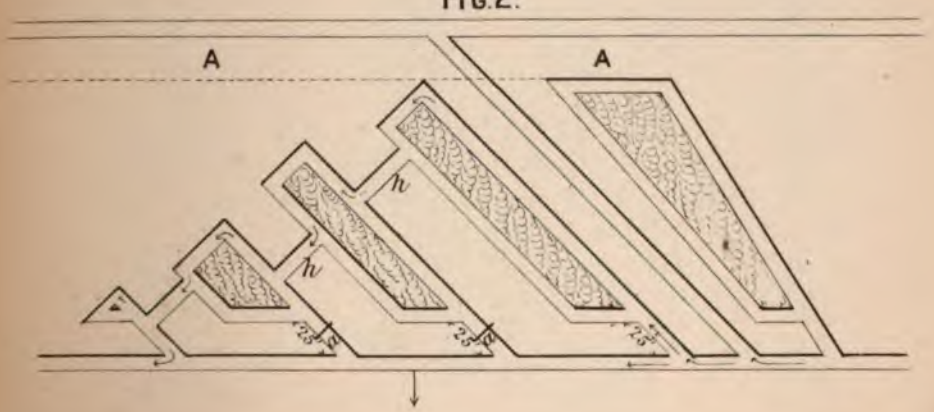


b. Stopping.
a. Doors.
c. Travelling Road.
d. Inclined Plane.

Breadth of Board 34 ft
" of Pillars 137 "

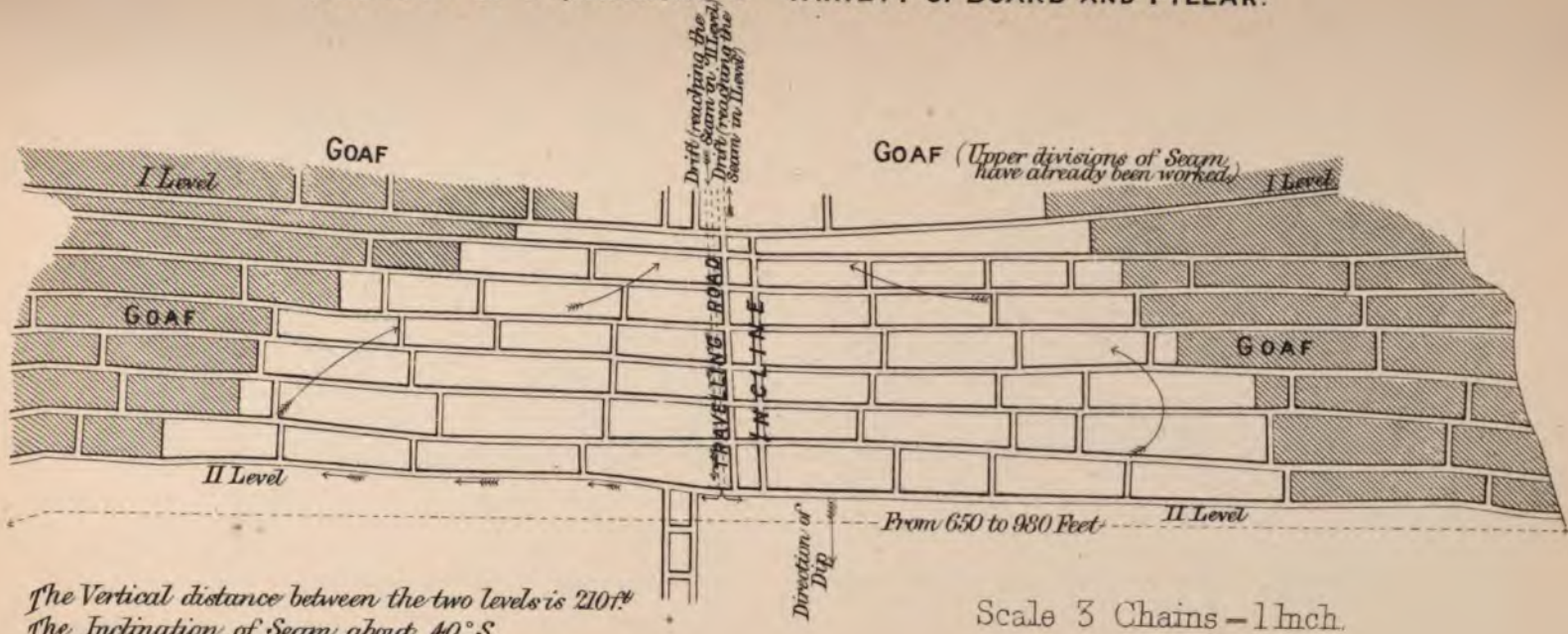
Board and Pillar (Second Variety.)

Fig. 2.



To illustrate Mr A. R. Sawyer's paper "On Mining at Saarbrücken."

COPY TAKEN FROM PLAN OF BLUCHER SEAM AT SULZBACH COLLIERY.
(REDUCED BY $\frac{1}{3}$ RD.) SHEWING 3RD VARIETY OF BOARD AND PILLAR.



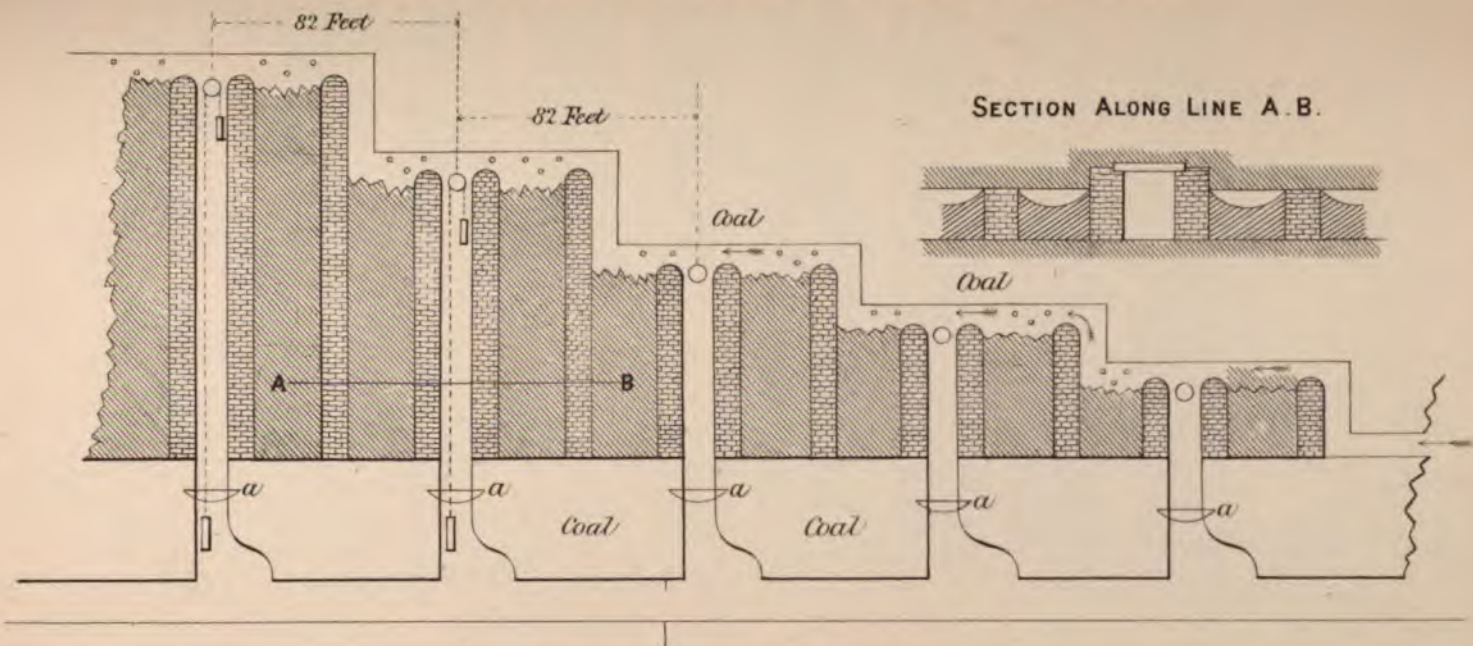
The Vertical distance between the two levels is 210ft
The Inclination of Seam about 40° S.

Scale 3 Chains – 1 Inch.

And.w Reid, Newcastle

To illustrate Mr. A. R. Sawyer's paper "On Mining at Saarbrücken."

LONGWALL IN THE CARL SEAM AT GERHARD COLLIERY.

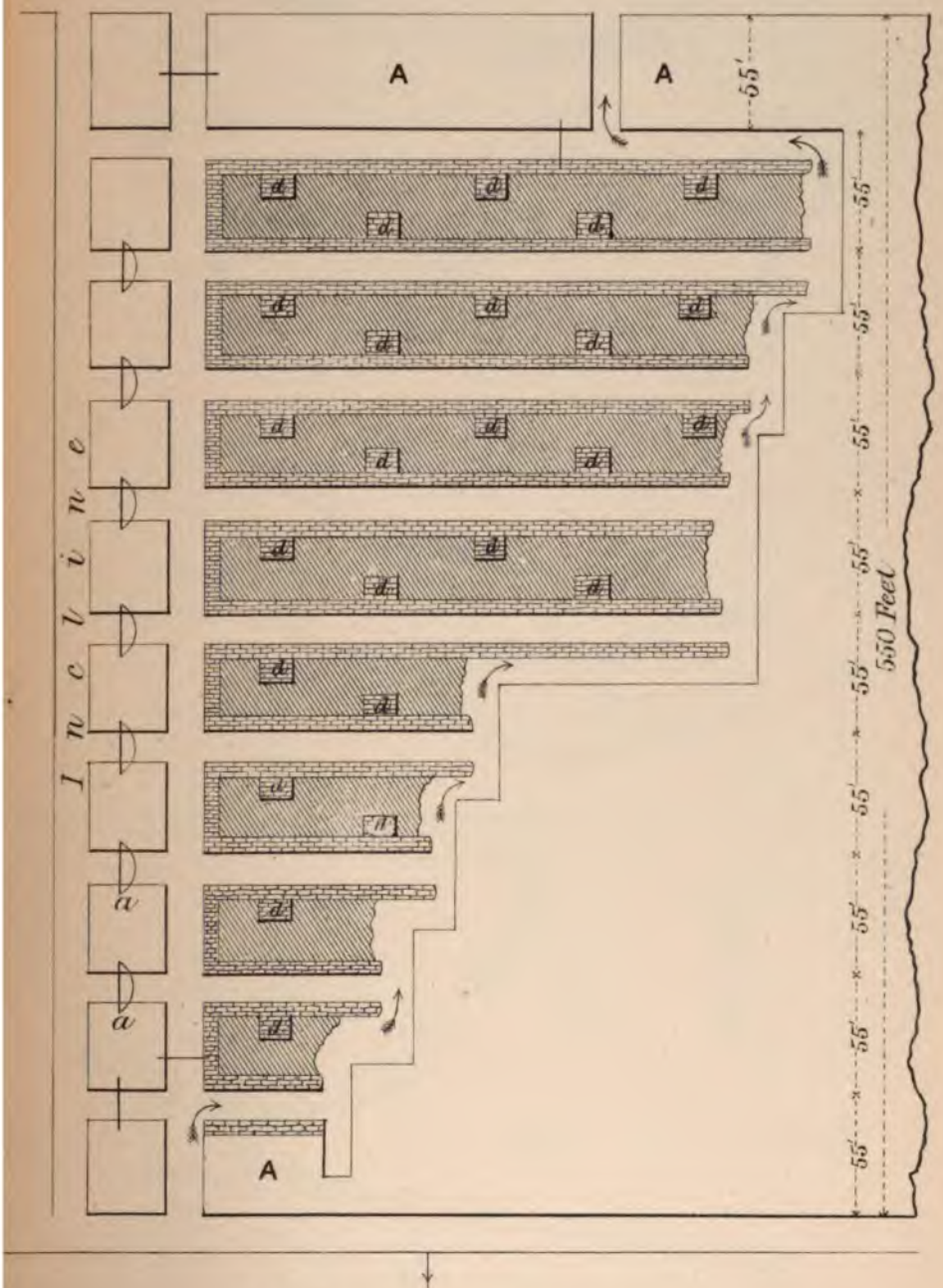


Length of each Stall 82 ft. *a. a. Doors.*

Proceedings N.E.I. of M. & M.E. 1878-79

To illustrate Mr. A.R. Sawyer's paper "On Mining at Saarbrücken."

LONGWALL IN THE MAX SEAM AT GERHARD COLLIERY.



d. Chocks.
A. Pillars left for support of Roads.
a. Doors.

To illustrate Mr A.R. Sawyer's paper "On Mining at Saarbrücken."

FIG. 1.

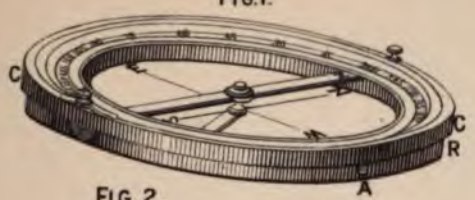


FIG. 2.

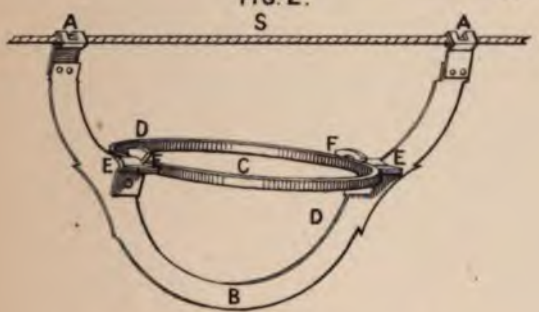


FIG. 3

FIG. 4.

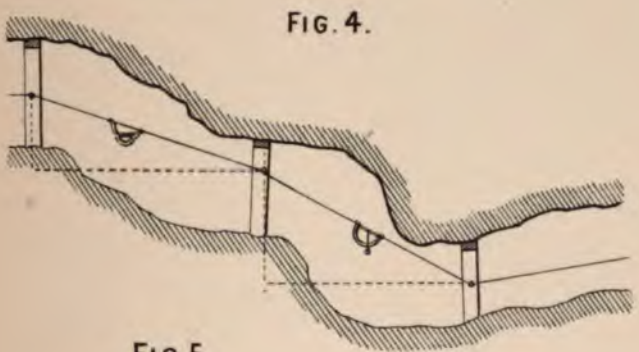


FIG. 5.

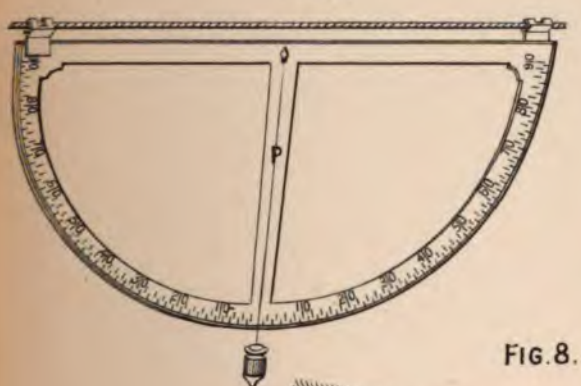


FIG. 6.

FIG. 7.

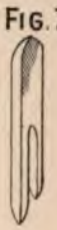
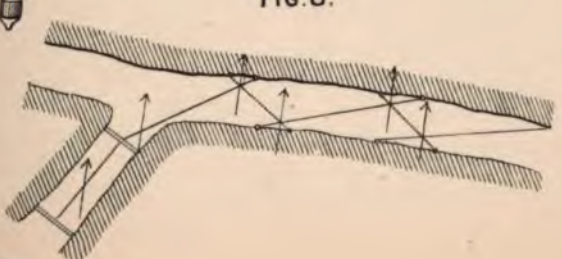


FIG. 8.



...nd Meiklejon's Coal cutting Machine.

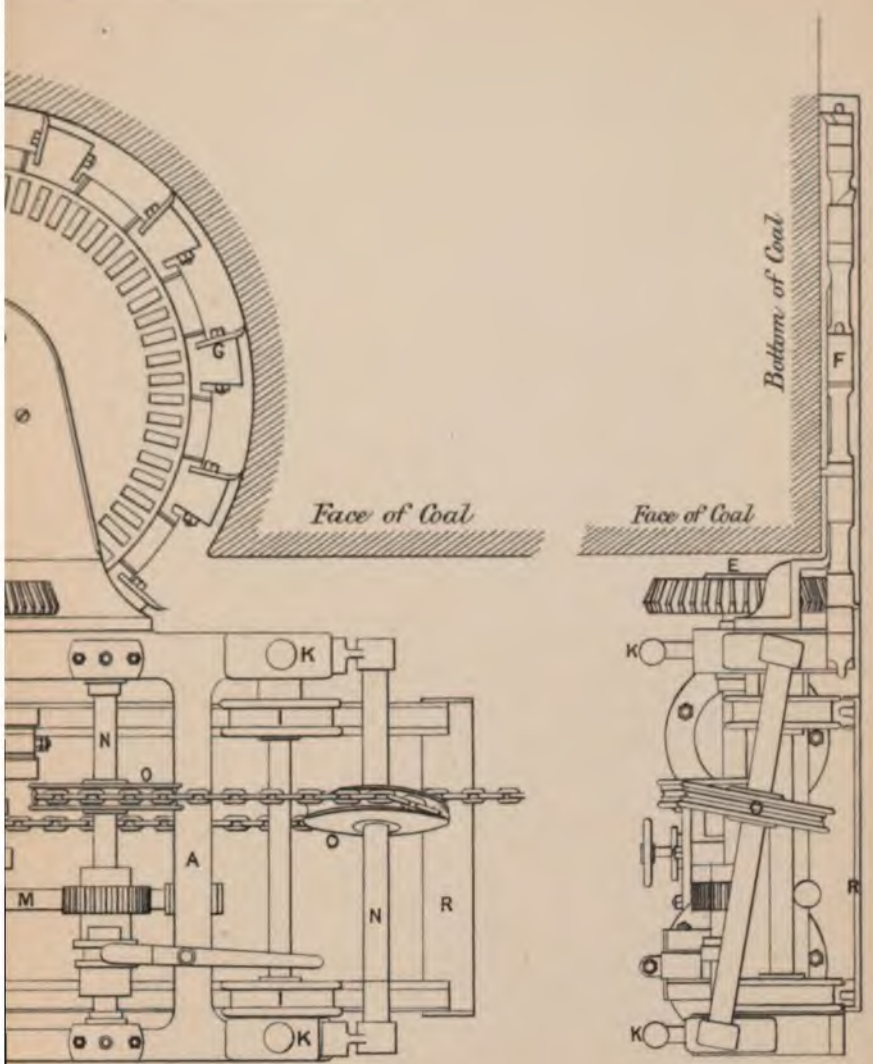
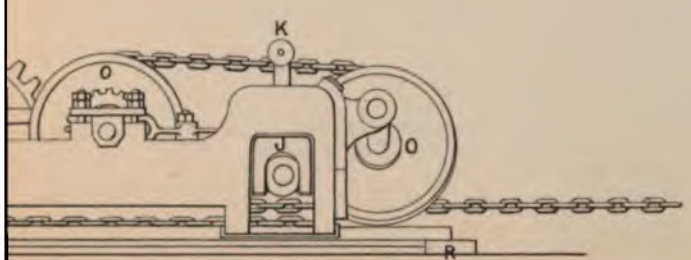


FIG. 3.



To illustrate M.r D.P. Morisons description o

FIG. 1.

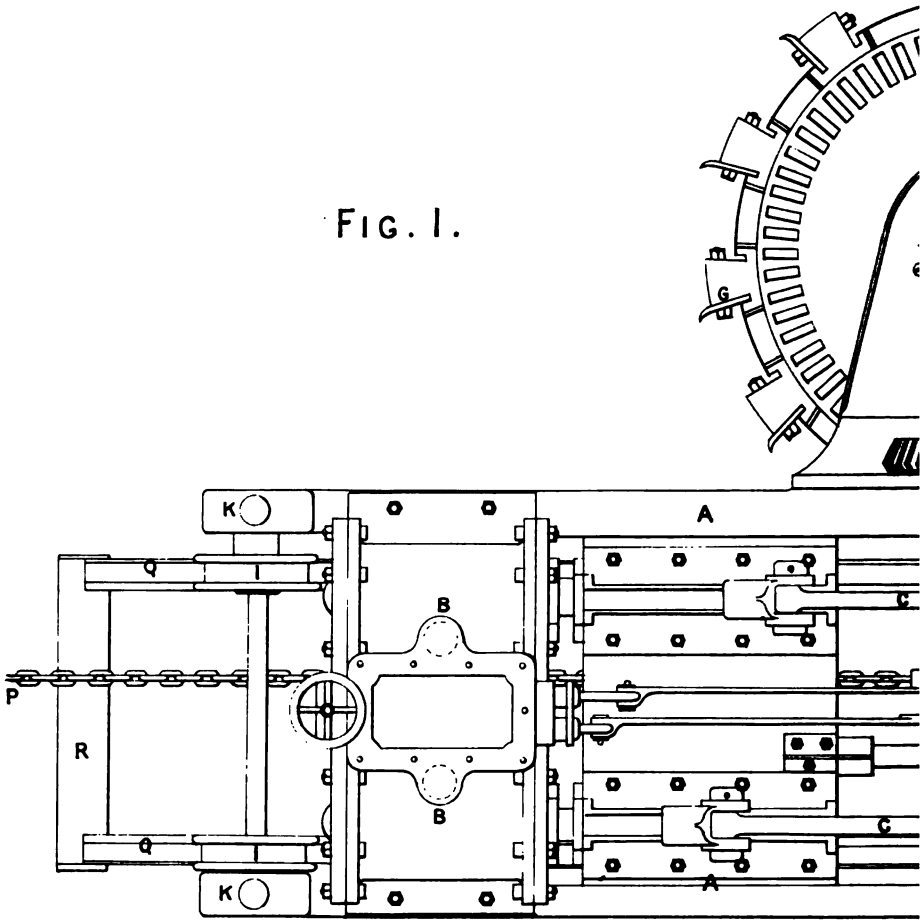
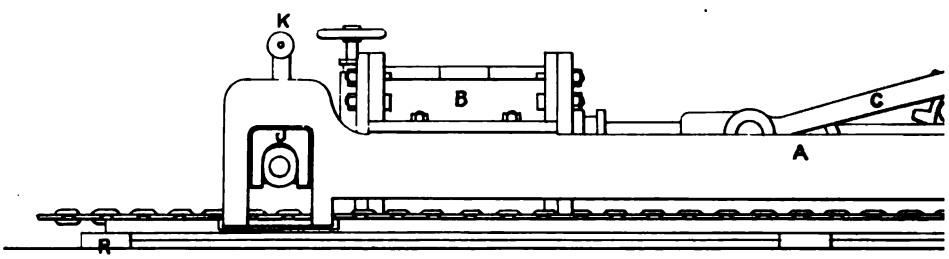


FIG. 2.



Inventions No. 1 of M.r M.E. A.D. 1879

Mr. LEBOUR said, he had asked the question because it seemed to him that these Griesborn beds formed the most distinguishable horizon in the whole of the Saarbrücken coal-field, so far as the coal-measures were concerned, and allowed a line of division to be taken between the Lower and Upper Saarbrücken measures far clearer than such lines usually were. The Ottweiler series was not a very distinct one stratigraphically, although palæontologically it was perhaps a good one. Assuming these Griesborn beds to be the top division of the coal-measures, they afforded a means of correlating the age of the Saarbrücken coal-field with that of the coal-fields of France on the one hand, and those of Bohemia on the other. From the best evidence at his disposal it would appear that the Griesborn beds were well represented by the Shadowitz deposits in Bohemia, and by the St. Etienne and other southern French coal deposits; whereas the lower parts of the Saar coal-measures below the Griesborn beds were the representatives of the English coal-measures and of those of Belgium, Northern France, and of the Lower coal-measures of Bohemia. There was nothing left of the true coal-measures to correspond with the Ottweiler beds, so far as he knew, either in Bohemia or in any of the French or Belgian coal districts. Now, as Mr. Sawyer had clearly explained, there was on the Saar a perfect succession from the coal-measures to the Permian, and the passage from one to the other was so imperceptible that it was difficult to draw any line between them. He (Mr. Lebour) thought it might some day be shown that the Ottweiler division was really what was called the Permo-Carboniferous in North America, and in other countries where there was no unconformity between the Permian and the coal-measures; and if he might throw out the merest suggestion, he would say that probably the nearest approach in England to the Ottweiler beds was the uppermost coal-measures in that part of Staffordshire where the unconformity of the Permian was the least marked, and where it might turn out that there was no unconformity at all. He had been extremely pleased to see what a thoroughly geological paper Mr. Sawyer had produced, especially as he (Mr. Lebour) had thought from the title of the paper that it would treat chiefly of mining proper.

The PRESIDENT asked Mr. Sawyer whether there were any limestones in these upper coal-measures?

Mr. SAWYER—There are a few very thin beds of limited area amongst the Ottweiler rocks. Amongst the Saarbrücken rocks there is a bed of calcspar and dolomite at Jägersfreude, one to two inches thick; it is limited in area, and lies immediately above a bed of hematite. There are also two or three beds of limestone, of from ten to twelve inches in thickness,

lying close together at Guichenbach. They have a dolomitic and concretionary character, and are impure; their area is also limited.

The PRESIDENT asked if they were freshwater or marine limestones?

Mr. SAWYER said they were freshwater. In the Ottweiler limestones, the bivalve crustacean Estheria, as well as Anthracosia and fish remains, have been found.

The PRESIDENT asked if that would imply any connection between these beds and the upper Lancashire beds?

Mr. SAWYER—Yes, in so far as presence of non-marine limestone is concerned. The limestone beds of Ardwick, near Manchester, are, however, very much thicker and more important than those of Saarbrücken.

The PRESIDENT—And the same as those south of Shrewsbury and at Nuneaton, &c.?

Mr. SAWYER—Most probably, for the same reason.

The PRESIDENT—Yes, he should think it very likely indeed. There was another question he would like to ask with respect to what Mr. Sawyer had said about the faults not going through the red sandstone, or not through the Permian: was that universally the case, or were there any exceptions to it?

Mr. SAWYER said, he did not think there was a single exception, although it was stated that there was.

The PRESIDENT said, he did not understand when the paper was read, whether Mr. Sawyer meant that the faults did or did not go through the Permian.

Mr. SAWYER—Through the Permian but not through the Trias.

Mr. LEBOUR said, there was no conformity between the Permian and the coal-measures. The faults stopped at the Bunter. Might he ask what Mr. Sawyer understood by melaphyre?

Mr. SAWYER—An altered basalt or dolerite. A basic eruptive rock.

Mr. LEBOUR asked if Mr. Sawyer meant any special kind?

Mr. SAWYER—No.

The PRESIDENT asked Mr. Sawyer whether he had seen any of the limestones himself?

Mr. SAWYER said, he had not noticed the limestone beds particularly, as it was not easy to get at them.

The PRESIDENT said, if there were any Spirorbis Carbonareus in these limestones it would tend to show the identity between them and the others he had referred to.

Mr. LEBOUR said, that was very likely indeed: they seemed to know very little about these Ottweiler beds in the district; they were not mined

so much, and not so well exposed at the surface as the lower and more richly coal-bearing beds.

Mr. HENRY HALL said, the author had made a comparison as to accidents in England and in Prussia: he would like to ask at what depths these coals were generally worked?

Mr. SAWYER said, the depth at which coal is at present worked varies from about 300 to over 1,000 feet. The deepest shafts are those recently sunk in the Fischbach valley, which are very nearly 2,000 feet deep. Though the average depth at which the coal is at present worked is less than that at which it is worked in most of the English coal-fields, yet the difficulties encountered in working, from the great number of faults, bad roof, steep inclination of seams, and especially from fires, are very great. These fires were due to spontaneous combustion, and the one he had described, which took place at the outcrop of the Blücher seam, was caused by the presence of pyrites, which occurs not in the coal itself but in the cleat planes. The men worked both with safety lamps and also with naked lights, and no explosions on a large scale have occurred as yet, but now and then there are small explosions where two or three men are killed. These remarks apply to the Saarbrücken coal-field only.

The PRESIDENT asked if the members were to infer from the paper that the number of accidents which happened there from other causes than explosions were more numerous than in England?

Mr. SAWYER—Yes, especially accidents from falls of stone. As will be seen in the tables, the number of deaths per men employed is greater in the Westphalian Coal-field than at Saarbrücken; the death-rate in Saarbrücken is smaller than in England. Mr. Simpson has shown in one of his papers that the death-rate in the whole of Germany is greater than in England; but at Saarbrücken alone it is smaller.

The PRESIDENT said, the next business before them was the discussion of a paper on the "Telephonic Ventilation Tell-tale," by Mr. Henry Hall. He was glad to see Mr. Hall present; and he would ask, in the first place, whether he (Mr. Hall) had himself any further remarks to make on the paper?

Mr. HALL said, he had nothing to add to the description of the "Ventilation Tell-tale" given in the paper, which was read a few months ago, excepting that since that time the Tell-tale had been adopted at some collieries near Wigan, and had proved to be perfectly reliable and very useful to the managers. The makers now hoped to be able to enter into such an arrangement with the Telephone Company as would enable

them to offer it at a very reasonable price. If any gentleman wished for any explanation respecting it he would be happy to give it.

The PRESIDENT asked if the communication was to the bottom of the pit?

Mr. HALL replied that the anemometer was fixed in one of the main air-ways, and the reading was taken at the office on the surface.

The PRESIDENT asked whether it was used for any other purpose of communication than simply for indicating the state of the number of revolutions of the anemometer?

Mr. HALL replied that it was used simply for measuring the air. It might be used for speaking purposes, but it had not yet been so used.

The PRESIDENT asked the names of the collieries where it was being used?

Mr. HALL replied that the instrument was in use at Pemberton, at White Moss, and at one of the Wigan Coal and Iron Company's pits.

The PRESIDENT asked if the Pemberton Pit was not between 500 and 600 yards deep?

Mr. HALL—Yes, it was a great depth, and the wire was carried a long way along the surface to the office.

Mr. R. F. BOYD asked Mr. Hall whether it was possible to have more than one anemometer fixed upon the Tell-tale, so that all the air-ways might be registered in the office?

Mr. HALL said, that only one anemometer could be attached to a wire, but one telephone would record any number of anemometers through separate wires, so that any extra expense would be for anemometers and wires and not for telephones. The wire must come from the instrument to the office, or to any other desired place.

The meeting then separated.

PROCEEDINGS.

GENERAL MEETING, SATURDAY, OCTOBER 5TH, 1878, IN THE WOOD MEMORIAL HALL.

G. C. GREENWELL, ESQ., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last general meeting, the minutes of the Council meeting of September 7th, and the minutes of the Council meeting of September 28th.

The following gentlemen were then elected :—

ORDINARY MEMBER—

Mr. HENRY BRAMALL, M.I.C.E., St. Helen's, Lancashire.

ASSOCIATES—

Mr. NATHAN MILLER, Kurhurballa Collieries, East India Railway, Chord Line, Bengal.

Mr. W. S. GRESLEY, Overseale, Ashby-de-la-Zouch.

STUDENTS—

Mr. ROBERT BUCKHAM, East Pontop Colliery, Lintz Green.

Mr. EDWARD F. MELLY, Nunnery Colliery Offices, Sheffield.

The following were nominated for election at the next meeting :—

ORDINARY MEMBERS—

Mr. WILLIAM ACKROYD, JUN., M.E., Morley Main Colliery, Morley, near Leeds.

Mr. WILLIAM ROGERS, M.E., King Street, Wigan.

ASSOCIATE—

Mr. J. BAGNOLD SMITH, M.E., The Laurels, Chesterfield.

STUDENTS—

Mr. HENRY PALMER, Nunnery Colliery, Sheffield.

Mr. ROBERT F. SPENCE, Surveyor, Backworth Colliery, Newcastle-on-Tyne.

DEATH OF MR. J. T. WOODHOUSE.

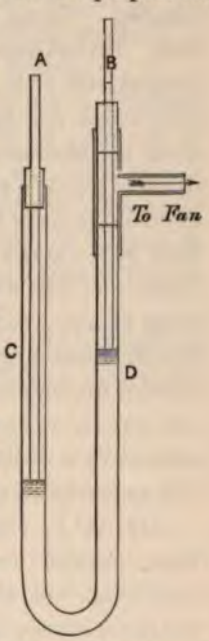
The PRESIDENT said, he felt sure that every one would hear with regret that Mr. John Thomas Woodhouse, an old and respected member of the Institute, had departed from amongst them, and had been buried yesterday. Of no one could it be said more truly that those who knew him best respected him most. He himself had known Mr. Woodhouse for more than twenty years. He had met him frequently in business in different parts of the country, and certainly could safely say that a more genial, upright, honourable, and able man could not be found.

Mr. FREIRE-MARRECO then read the following paper "On a Recording Water Gauge for Pit purposes."

RECORDING WATER GAUGE FOR PIT PURPOSES.

By A. FREIRE-MARRECO.

Mr. Freire-Marreco said, that he had occasion, in the course of some experiments which he had been lately making, in conjunction with other gentlemen, upon coal dust, and the results of which he hoped would very shortly be laid before the Institute, to devise some gauge which should indicate, as quickly as possible, sudden and transitory variations of tension —which should record, in fact, an air-push, if he might so call it, lasting only a few seconds; and so this instrument was constructed (which he might just say, in passing, turned out entirely useless for the purpose for which it was wanted), which seemed sufficiently near to a "recording gauge" to be worth laying before the Institute. He should also say, in the first instance, that there was really nothing new in the principle, as Sir William Thompson, if he (the speaker) was not mistaken, had utilised recently the same principle in some of his sounding experiments. The instrument on the table consisted of an ordinary U tube, but instead of being charged with water, it was charged with a very weak solution of chloride of iron, which recorded any change made in the level of the solution by changing the colour of strips of paper soaked in yellow prussiate of potash (better known to some as ferrocyanide of potassium), secured to strips of glass by some gelatinous substance. He had purposely exhibited, not one of the gauges such as were now at work, but the original working model which had been standing idle for something like a couple of months, so as to show that the maximum and minimum water line were really fairly well recorded by a distinct blue line, even after that lapse of time. The woodcut shows the arrangement of the tube CD, and the glass indices AB, which latter, when the instrument is set, must be pushed down till they just touch the liquid in both limbs of the tube, when any change



will be marked either on the outer or inner strip of glass, the marking on the outer (C) strip showing the minimum, and that on the inner (D) the maximum pressure. If there is no mark on the outer strip, the minimum pressure is that existing at the time the indices were set. Of course, a very much simpler arrangement could be put together when it was only wanted to show that the minimum pressure had been kept up. As to the preparation of the indices, he did not know that they were yet absolutely perfect; but he had tried a good many variations both as to materials and construction, and the thing which he had settled on at last (and which they would be exceedingly glad to put into the hands of anybody who wished to try it) was this: the paper was prepared in the first instance by soaking it in yellow prussiate and drying it, preferably in a dark room or drawer so as not to expose it too much to the light, and then sizing it down on thin strips of glass with the strongest solution of isinglass that could be used. If used without sizing, the line would invariably "creep" about an eighth of an inch on standing. Sizing, so far as he knew, was a pretty sure preventative of that. He had also tried a film of gelatine, which a professional friend in London was good enough to prepare, saturated with prussiate, cut into little strips, and fixed with water on the glass. That was a good deal more troublesome, and did not seem to much advantage. So far as he could see the present form was sufficiently good for practical work, but he would be sorry to give an opinion upon that subject. Mr. May had been good enough to set up this water gauge on the large Guibal fan at Hilda, and Mr. Steavenson upon another. He must apologise for not being able to give their results. He had only just returned to Newcastle, but Mr. Steavenson was present, and he hoped would be able to tell them whether the instrument worked satisfactorily. He should be only too glad if any number of members of the Institute would give the instrument a trial, and see whether or no it supplied a want. If so, he would think he had accomplished something.

Mr. D. P. Morison said, he thought the water gauge which had been described would be of very great use, not only for mechanical ventilation, but also for furnaces, inasmuch as whether the slips were put in for a year, for a week, or for a month, if taken out at the end of that time and registered, they would show during any particular period of time —whatever might be decided upon—the lowest and the highest water gauge which had been obtained during the interval; and in cases where an accident had occurred in the returns it would be a matter of very great interest to find from the register if the water gauge had sensibly

diminished or increased since it was last set; and it might be hoped that, in time, the instrument might be so perfected as to register the precise time when the fluctuations occurred. He thought, therefore, that every practical man would thank Professor Marreco very deeply for having brought out a thing, which, although at present, as Professor Marreco had said, was in a crude state, would evidently be so perfected as to become a valuable register of the friction in the airways and mines. He believed that it could with advantage be applied to Ramsay's water gauge; the difference between which and the ordinary water gauge was that the aperture between the two compartments in Ramsay's was exceedingly small, and the two limbs very large; and therefore the variation of the level of the fluid did not oscillate so rapidly as in the common water gauge; and with Ramsay's water gauge he believed it would prove a most valuable adjunct to a register of currents of air.

Mr. FREIRE-MARRECO said, there was not the slightest difficulty in working the instrument if a few small details were mastered, and if anybody, more especially students of the Institute, liked to call at the laboratory, he would be very glad to offer any explanations necessary, as there might be a little trouble at first in preparing the indices.

The PRESIDENT said, they were exceedingly obliged to Professor Marreco for bringing that matter before them. Things were new or old by comparison. Professor Marreco said there was nothing new in this, inasmuch as it was used by Sir William Thompson; but so far as a great many of the members, and he could speak for himself at any rate, were concerned, it was new to them, and they were very much obliged to Professor Marreco for bringing it before them.

Mr. A. L. STEAVENSON said, he had been in Paris, and had not had time to try the gauge, but he would have it tried next week, and, at the discussion, be prepared with the results.

Mr. D. P. MORISON then read the following paper:—

NOTES ON RIGG AND MEIKLEJON'S COAL-CUTTING MACHINE.

By D. P. MORISON.

THE question of getting coal by machinery is one of such universal importance that the writer feels he needs no apology for introducing a few preliminary notes on the above system and its ascertained duty; at the same time, however, he must crave the indulgence of the members of this Institute for such a crude and hurried notice of the apparatus, a notice which is intended to pave the way for details of future experiments, and to afford those interested in the subject some idea of what may, under certain conditions, be achieved by mechanical hewing.

The machine (see Plate XV.) is the invention of Messrs. Rigg and Meiklejon, of Dalkeith, N.B., and is on what may be termed the circular saw system. The following is a short description of the apparatus:—

A is the frame supported on wheels; B B the two air cylinders driving the gear; C C connecting rods; D crank shaft; E bevil wheel geared into cutting wheel or disc; F disc or cutting wheel, to which the cutters G are attached; H arm or bracket carrying disc; I wheels on which the machine is carried; J axle boxes; K four screws by which the machine may be raised or lowered in any direction to suit the inclination of the bed or seam; L worm giving motion to propelling shaft; M N N shafts bearing the progressing chain wheels O O by which the travelling of the machine along the face is regulated; P propelling chain; Q rails on which the machine advances; R sleepers.

The main advantages claimed by the inventors are—

1.—The machine is so constructed as to hole or cut in the face to the bottom or under side of the sleeper supporting the rails; or, in other words, flush with the *thill* or bottom.

2.—The height of the machine, being under 16 inches, enables it to be employed in thin seams, which would otherwise be expensive to work.

3.—The arrangement of endless chain or rope for dragging is improved and simplified.

4.—The arrangement of the four adjusting screws at each corner by which the cutter can be made to work at any suitable angle.

5.—The axle boxes are also so adjustable as to allow of the machine progressing when at any angle, irrespective of the level of the rails and sleepers.

6.—The arrangement for holding the teeth or cutters by which any number and any shape can be employed according to the nature of the material to be operated upon.

The machine has now been at work at Penston (one of Messrs. Dean and Moore's collieries) for some eighteen months, and has given great satisfaction. The following particulars of its performance have been kindly supplied to the writer.

The coal, which varies in thickness from 22 inches to 30 inches, is hard and similar in character to the part of the seam in which the "kirving" was done in the latest experiments, by this and other machines, at Elemore, Hetton. It is worked on the "long-wall" system, the face being usually some 200 yards long. The machine is supplied with compressed air by two air cylinders 16 inches diameter and 3 feet stroke, varying in pressure from 35 lbs. to 45 lbs. The labour entailed by the machine is supplied by three men and one boy, who use naked lights (the usual Scotch lamps), the coal being holed in the night shift of nine hours, and filled during the day.

The following is an abstract of the work done by the machine over an average of ten days when fully employed:—

STATEMENT OF CUTTING DONE BY MACHINE IN MESSRS. DEAN AND MOORE'S PIT, AT PENSTON, WEST OF HADDINGTON.

Days and Date.			No. of Yards cut per Shift.	Remarks.
July	22.	Monday	150	
„	23.	Tuesday	Idle.	Coal not lifted on previous day.
„	24.	Wednesday	150	
„	25.	Thursday	150	
„	26.	Friday	150	
„	27.	Saturday	150	
„	29.	Monday	150	
„	30.	Tuesday	Idle.	Coal not lifted on previous day.
„	31.	Wednesday	150	
Aug.	1.	Thursday	150	
„	2.	Friday	150	
„	3.	Saturday	110	Small wheel broke.

N.B.—A shift consists of nine hours on an average.

This represents a total of 1,460 yards cut, or 146 yards per shift of nine hours—16¼ yards per hour—the kirving being on an average three feet two inches into the coal and a width or height of three inches.

One of these machines is now in operation at Elemore (one of the Hetton collieries), where several other systems have been previously tried. The result of cutting per eight hours' shift compares rather unfavourably with the Penston performance, but per hour the work done is very creditable. The reasons of the slow progress of the machine may be summarised as—

1.—The sleepers and rails having to be blocked up in front of the machine, some 8 or 10 inches, so as to allow the machine to cut in the top coal.

2.—On account of this insecure mode of constructing the tramway, the liability of the jib and disc to strike up in the coal, and then requiring to be hewn out.

3.—The fact of the men sent from Scotland being unaccustomed to the faint light afforded by Davy-lamps; and also, (after their departure) the men kindly supplied by the Hetton Company being unused to the machine.

The following is an abstract of the work done per shift from July 30 to September 19:—

STATEMENT OF CUTTING DONE AT ELEMORE COLLIERY, HETTON.

Date.	Yards Cut.	Time Cutting.	Date.	Yards Cut.	Time Cutting.
1878.	Yds. Ft.	Hr. Min.	1878.	Yds. Ft.	Hr. Min.
July 30	47 0	1 35	Sept. 1	30 0	1 5
Aug. 1	50 0	2 0	„ 9	15 0	32
„ 7	10 0	21	„ 10	47 0	1 30
„ 8	18 0	40	„ 11	13 0	1 8
„ 9	32 0	1 13	„ 17	13 0	28
„ 12	57 0	1 48	„ 18	37 0	1 20
„ 16	29 0	59	„ 19	56 0	2 15
„ 19	60 0	1 44			
„ 22	20 0	43			
„ 29	47 0	1 7			
„ 30	29 0	1 4			

This represents an average (excluding Sept. 11) of 29 yards of coal kirved—3 feet deep and 3 inches wide—in one hour.

If the machine could be placed in more favourable conditions, the amount of work per hour claimed by the inventor (viz., sixty yards) would possibly be obtained, but even at the comparatively modest result

of thirty yards per hour the apparatus will commend itself to the attention of the mining world.

The following statement of prime cost and annual maintenance has been submitted to the writer, and the cost, as compared with hand labour, appears very satisfactory :—

COST OF PLANT TO PRODUCE 100 TONS OF COAL PER SHIFT, THE SEAM OF COAL BEING 2 FEET THICK AND VERY HARD.

One steam boiler, with fittings complete	£350
One air-compressing engine, with steam engine combined	570
One air receiver	80
Foundations and buildings in connection with above	400
One machine, with rails and sleepers	250
Steam and air pipes, with connections	150
Allow for incidental expenses	200
	£2,000

COST PER ANNUM.

Interest on £2,000 @ 5 %	£100
Depreciation of machinery @ 5 %	100
Repairs on do.	100
Stores, including steel for cutters, etc.	100
Coal for steam boiler, 600 tons @ 6s. per ton	180
Coal for smithy	15
Fireman	65
Blacksmith for sharpening cutters, etc.	78
3 men attending machine, 8s. each per day = 260 days @ 24s. ...	312
1 boy ... ... 260 days @ 3s. ...	39
	£1,089

£1,089 to produce 26,000 tons coal = about 10d. per ton for holing, hewing, and kirving.

It is the writer's intention to have a tabulated statement prepared before the discussion, showing the economy to be obtained by the use of the machine, especially in the hard steam coal districts of the north; and he trusts the foregoing particulars may suffice to enable some of the members to provide useful data for comparison.

The PRESIDENT said, that it would probably be advisable not to express any opinion respecting the machine now, but simply to make such inquiries as would indicate to Mr. Morison the information that would be most appreciated, and he for one hoped that full information would be

given them of the hardness and nature of the seams of coal in which the machine had been worked, and if applicable to kirving out black stone or shale bands.

Mr. MORISON said, he would be very glad if any enquiries of that kind were made to-day, and should be only too happy to meet the views of the president and members.

Mr. WILLIS asked what was the weight of the machine?

Mr. MORISON—Twenty-five cwts.

Mr. T. LINDSAY GALLOWAY asked whether this machine was capable of cutting itself into the coal—supposing it was working long-wall, and not taking off pillars, and it came to a fast end, whether the jib could swing round in such a way that the machine itself was capable of winning out its own coal, or had the coal to be won by men? Another question which he would like to ask was, whether there was any difficulty in keeping the machine close up to the face? In the Gartsherrie machine, which he had seen at work at Auchenraith Colliery, there was a very great difficulty in that respect. They had to put props expressly, along the whole length of the cut, and to place sleepers longitudinally between them and the rails so as to keep the machine close up against the face, otherwise the machine got away from the work, and caused a long stop. He could only say that the results furnished to the meeting by Mr. Morison, of what the machine achieved in actual practice, seemed very favourable as compared with the results of the Gartsherrie machine. That machine cut 60 yards in one shift, and produced 90 tons of coal. The seam, however, was $4\frac{1}{2}$ feet thick; therefore, they must not take merely the quantity of coal produced without considering that the seam in the case given by Mr. Morison was much thinner. There were a few other particulars regarding this machine which he happened to have with him. It had an eight-inch cylinder, 14 inch stroke, was of 17 horse-power, and worked 320 strokes per minute, and seemed to go rather irregularly. He could only say it would be a very great achievement in the application of coal-cutting machinery, if such a machine as that which had been described by Mr. Morison could be made to work practically, in the way it appeared to have done hitherto.

Mr. MORISON stated, in reply to Mr. Galloway, that the machine had a fixed jib; consequently, in order to allow it to cut three feet into the coal, a holing would have to be made at the end of the long-wall face, in order to allow it to start fair. It was quite evident that this must be the case unless the jib was moveable. He thought, however, that it had been pretty well proved that moveable jibs were insecure, and continually getting out of order, and that the more

solid and compact the machine could be made the better. When once started in the nick prepared for it, no difficulty had been experienced in keeping the machine at the proper distance from the face. The mode of progression was simply by a chain passing over pulleys, with teeth fitting into each link. These pulleys were driven by means of a worm, and the speed could be regulated to suit hard and soft coal.

Mr. LAWRENCE said, that after the President had recommended that no discussion should take place till the paper and drawings were in the hands of the members, he was rather surprised at the remarks that had been made at the meeting. He (Mr. L.) had been interested in the working of coal-hewing machines during about eighteen or nineteen years, and he was most anxious to have before him all the details of the cutter Mr. Morison had been kind enough to describe. The remarks made by Mr. Galloway were most appropriate. They were aware that in the Baird machine the cutters were placed on a chain, which might be described as the chain of a dredger laid horizontally instead of working perpendicularly; and the cutters of themselves going in from an opening in the long-wall, which had to be cut in to admit it the same as with this machine. The cutters have a tendency of always drawing the machine on towards the face of the coal, and there was also a tendency to throw the machine off the way. Messrs. Baird and Co. got over this difficulty by simply having posts fixed to each end of the long-wall, whereby the machine would pull itself along. These posts were not fixed in the centre of the way, but at such a distance from the face of the coal as to put a strain on the machine as it progressed, tending to draw it from the face, and counteract the tendency of the cutter to pull it over towards the face. He thought it would be quite unfair to Mr. Morison to discuss the merits of the machine at present.

The PRESIDENT said, it was the intention that the discussion was not to go on; but the fact was that what had been stated by Mr. Galloway and one or two other gentlemen, was simply in answer to Mr. Morison's request that if there was any information which he could get for the benefit of the Institute, he would be very happy to embody it in the application he was about to make to the inventors of the machine.

Mr. MORISON said Mr. Lawrence must quite understand that he (Mr. M.) had nothing whatever to do with the invention of the machine, and the only reason for bringing the subject before the members of the Institute was in order that they might have an opportunity of considering a subject which would interest them, and on which they might have a valuable discussion; and he added that if any gentlemen connected with the Institute would kindly drop him a note, he would be very glad,

having the kind permission of the Hetton Colliery owners, to accompany them over to see the machine; and perhaps Mr. Lawrence, who wanted particularly to know all the details of it, would also join, and act as guide to explain by his experience what the machine would do.

The PRESIDENT said, the next business was the discussion of Mr. T. Lindsay Galloway's paper, "On the present condition of Mining in some of the principal Coal-producing Districts of the Continent." The paper was so clearly written, and so explained itself, that really there did not seem to be much to discuss. He supposed that was the reason why the members present did not seem to have anything to say.

Mr. STEAVENSON thought that was really the reason of their not having a discussion upon it. He had heard the paper spoken of more than once as being a very excellent and complete one. It would be a great addition to their Transactions, and he thought it only remained for them to pass a vote of thanks to the writer of the paper.

Mr. RAMSAY begged to second the motion, which was unanimously carried, and the meeting then terminated.

PROCEEDINGS.

ANNUAL GENERAL MEETING, SATURDAY, NOVEMBER 2, 1878, IN THE LECTURE ROOM OF THE COLLEGE OF PHYSICAL SCIENCE, NEWCASTLE-UPON-TYNE.

G. C. GREENWELL, ESQ., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting and reported the proceedings of the Council.

The following gentlemen were elected, having been previously nominated:—

ORDINARY MEMBER—

Mr. WILLIAM ROGERS, M.E., King Street, Wigan.

ASSOCIATE—

Mr. J. BAGNOLD SMITH, M.E., The Laurels, Chesterfield.

STUDENTS—

Mr. HENRY PALMER, Nunnery Colliery, Sheffield.

Mr. ROBERT F. SPENCE, Backworth Colliery, Newcastle-on-Tyne.

The following gentlemen were nominated for election at the next meeting:—

ASSOCIATES—

Mr. WILLIAM PRICHARD, M.E., Navigation and Deep Duffryn Collieries, Mountain Ash, South Wales.

Mr. JOHN THOMPSON, Underviewer, Heworth Colliery, Co. of Durham.

Mr. FREIRE-MARRECO then read the following paper:—"An Account of some recent Experiments with Coal Dust."

AN ACCOUNT OF SOME RECENT EXPERIMENTS WITH COAL DUST.

By A. FREIRE-MARRECO and D. P. MORISON.

This paper, although it has been delayed longer than the authors wished or expected, must still be regarded only as a preliminary one, because they hope it will induce further experiments on the part of others; and although the paper is described as being the joint production of Mr. Freire-Marreco and Mr. Morison, its authorship should not have been so restricted, because, as the details of the experiments which have been carried out are gone into, it will be seen that this paper could not have been written without the assistance of many others, whose names do not appear as authors, although they were really so in very large part.

It is only comparatively recently that this subject has really been taken up in this country, though attention had been publicly directed to it as a possible source of pit accidents, and a good deal of work had been done upon it by M. Vital, and others, in French collieries. It is hardly necessary to go into the details of these experiments, because members will find them fully summarised in the very long and complete series of articles which Mr. Galloway has lately been publishing in *Iron*.

Two years ago, in March, 1876, Mr. Galloway communicated to the Royal Society the results of a set of experiments, the sum of which appeared to be this: that, taking a small quantity of fire-damp and mixing it with air, in the proportion of from 1 to 1½ per cent. of gas to air, a mixture was obtained, which, as might have been anticipated, neither exploded by itself nor showed upon the lamp; that, taking a mechanical mixture of coal dust and air, a mixture was obtained which was perfectly inert, at any rate as regarded a naked light, but that adding to the already gas-contaminated air just alluded to, the same quantity of coal dust, a mixture was produced which, even on a small scale, could be fired at a naked light, which would explode in a testing apparatus, and which would continue to burn, so long as the supply of gas and dust was kept up, with a dull red flame. Pushing the experiment a little further, Mr. Galloway

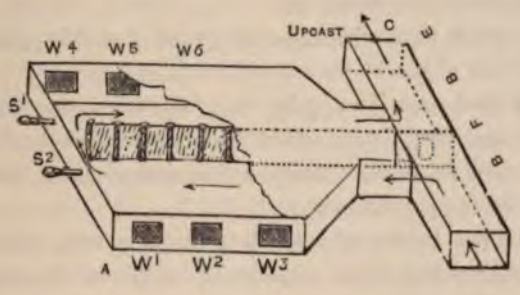
arrived at the conclusion that the small percentage of coal gas of which he speaks, and which, at that time, was hardly to be detected in practice by any test, was essential to the combustion of the coal-dust; or, to put it more plainly, that coal dust alone, added to an air current, produced a mixture which would not fire either at a lamp or at the gases from a powder shot.

That conclusion seemed to the authors to be to a certain extent doubtful, at any rate so far as concerns *all* coal dusts. It seemed just possible that the term "coal dust" was a generic rather than a specific word, and that they might distinguish "coal dust" from "coal dust," *e.g.*, cannel from anthracite. There was little doubt that the particular dust Mr. Galloway was working with did not satisfy the conditions required for an explosive mixture, but it seemed, to say the least, possible that other dusts—say, north country dust—might do so; and Mr. Galloway having announced, in the paper referred to, his intention of not pushing the inquiry further in that direction, the writers endeavoured to take it up, at first in a very rough way, in the laboratory of the College. It is not necessary to go into the particulars of these preliminary experiments, in which Mr. Cochrane was good enough to assist, further than to say that building out of the remnants of the "sound wave" apparatus and some old wooden boxes an imitation gallery, loading it with coal dust, creating a current through the apparatus with a model Guibal fan, and finally, firing a light pistol shot into the atmosphere, an effect was produced which, if not actually an explosion, was so near an approach to one on a small scale as to prove that the subject deserved further attention.

The next set of experiments was worked out at Elswick Colliery (by the kind permission of the owners) by Mr. Cochran Carr, Mr. Cochrane, and the authors. Into the details of these experiments it is hardly necessary go at any great length, because, in the first place, they have been published in detail elsewhere, viz., in the Transactions of the Chesterfield Institute; and, because, in the second place, they only amplified a little the result which had been arrived at in the laboratory. They seemed to prove still further, by the extent to which the box was damaged by the explosion, that there was something worth working out; but they hardly gave such evidence as could be placed before this Institute as proving the case.

It may not be out of place to give here a short description of these experiments, in order to show how they encouraged the authors to continue their researches:—

A deal box some eight feet in length, and of proportionate width, of the form shown in the following cut, was constructed in such a manner



as to represent a winning bord A driven narrow out of a headway B. Up the centre of this bord a length of brattice was run, supported by props, the whole representing on a small scale a working place. In the headway a door D was hung, and then one end of the headway C was inserted into the drift of a Guibal ventilator on the surface. The air then entered the opposite end of the headways and was drawn round the face by the door and the brattice, finding its exit at E to the fan drift, its velocity being regulated by a slide at F.

Three windows $W^{1\,2\,3}$ were placed at the west side of the box, and windows $W^{4\,5\,6}$ were placed on the east side, which, as well as the north end, being simply fastened on by hooks, or buttons, enabled the observers to note what occurred in the interior, "tell-tales" of paper were pinned on each side of the brattice at intervals of ten inches, both on brattice and floor. At the end of the box, representing the face of the bord, two holes were bored, into which were fitted two miniature cannons, representing in position and effect ordinary blown-out shots. These were loaded with a charge of powder, proportionate to the scale of the box, and lightly stemmed.

A quantity of coal dust, previously dried and sifted, was then procured, and stored at hand in readiness for the experiments.

The first experiments were performed with the box clean, and without coal dust. No effect was produced by the shots beyond the report of the cannons, and a small amount of smoke, which was soon cleared off by the current. The coal dust was then sprinkled over the floor, and blown against the sides and the brattice, door, props, etc. The following are the results obtained :—

1.—Shot fired from west side front of brattice, 30 grains of powder, slide closed, no current, box intact.

2.—Shot fired from west side, 60 grains of powder, slide closed, no current, east side of box blown out.

3.—Shot fired from west side, 90 grains of powder, slide closed, no current, east side of box blown out and north end sprung.

4.—Shot fired from west side, 120 grains of powder, slide closed, no current, east and north sides of box blown out, brattice and props blown down, west windows broken, flame at first west window, first and second tell-tales on floors were lighted.

5.—Shot fired from west side, 60 grains of powder, slide open, eight feet per second velocity of air, each side of box blown off slightly smoked, props blown down, tell-tales one on floor and one on brattice lighted.

6.—Shot fired from west side, 60 grains of powder, slide open, eight feet velocity, second window west side broken, flame observed at both, props blown down, no tell-tales fired.

7.—Shot fired from west side, regulator half open, velocity about six feet, 60 grains of powder, props blown down, tell-tales blown off but not fired.

8.—Both shots fired, west side first and east side twelve seconds afterwards, 60 grains of powder each, props blown down, tell-tales blown off but not fired, east side blown out-bye, east side dust much diminished.

9.—Both shots fired, west side first, east side two seconds after, props blown down, west window blown out, no tell-tales fired, considerable smoke.

10.—Both shots fired, west side first, east side two seconds after, 90 grains of powder each explosion, west side of box split, windows all broken, flame shown at east and west windows, dense smoke, box much damaged, props all down.

11.—Both shots fired, west side first, east side four seconds after, 90 grains of powder each, west side blew out east side of box and west windows, props all blown down, heavy smoke after west side, but no effect from east side, owing to east side of box being off.

12.—Both shots fired, west side first, east side four seconds after, 90 grains of powder each, brattice shifted and props down, screws on east side sprung, west windows out.

13.—Both shots fired, west side first and east side two seconds after, 90 grains of powder each, red flame at second east window, flame out of all west windows, props down in bord and in headways, box much charred and damaged.

14.—Both shots fired, west side first, east side three seconds after, 90 grains of powder each, flame first window west side after second shot, west windows blown out, east side sprung.

15.—Both shots fired, west side first, east side one second after, 120 grains of powder each, first shot had no effect, second shot broke all windows, flame travelled along bord into headways and was observed at intake, flame observed at first window west side, and at a supplementary window, flame shot out of west windows, smoke at regulator, box generally loosened.

16.—First shot fired from west side, 120 grains of powder, lighted dust at first window west side, blew out east side and blew down brattice, second shot from west side was consequently ineffective, box was then found to be too heavily damaged for further experiments.

It may be as well to point out here some of the difficulties which rendered these experiments a little tedious. It was required in the first place to have a perfectly still, perfectly dry, and tolerably warm day to work at bank with fine coal dust, and it seldom happened that when these conditions, not very often realised in this climate, came together, the other condition, of all the workers being able to come together, occurred. So that the experiments seemed very likely to come to an end but for the owners of Harton Colliery and Mr. George May, who placed at the writers' disposal, in a recently erected fitting shop, what can only be called an explosion-laboratory, in which they erected all the apparatus that could possibly be required for the experiments, and left it there from day to day, so that when an opportunity occurred, and the writers could get a day or half a day free from other work, there was the place waiting for them, and experiments could be proceeded with without any loss of time.

The apparatus used, consisted of a box shown in Plate XVI., divided into two parts, I and K, by a partition F. The portion I, about 12 feet long, and 6 inches square inside, was in immediate communication with the upright passage B (Figs. 2 and 4), through which air was forced and regulated by a slide, as shown. The other portion K, separated from the former by a partition F, is about 10 feet long, and is open to the air at D. Both sides of the box E and D are furnished with three windows, H^1, H^2, and H^3, through which the length of the flame produced by the firing of the two cannons A and C could be observed. These cannons were made of short pieces of gas pipe, closed at the end outside of the box, and communicating with the exploding apparatus described in the paper.

These experiments, and the apparatus used, were arranged so as, if possible, to carry out a definite idea. The idea was this: that if two shots could be arranged and fired into air, so as to imitate more or less closely the conditions under which coal dust might, in practice, get mixed with air,

and might then come into contact with shot gases, it would be seen whether under these conditions, which were probably the most trying they could have, any result could be obtained which might be fairly called an explosion. It was thought that if this condition of things could be arrived at by, first, a blown-out shot (from the face), firing *against* the air, as shown at A, Plate XVI., which might possibly lift up mechanically—purely mechanically—sufficient coal dust to constitute a more or less explosive mixture; and, second, by another shot C fired into this mixture as it came round the brattice, and so making it meet the shot gases, there would exist the most favourable conditions to produce, at any rate, an approach to an explosion.

This was attempted first at Elswick, as previously mentioned, with a considerably wider box, modelled to represent to scale the dimensions of a bord, but through which the air was drawn instead of being forced, but an almost insuperable difficulty was found—that was the getting off the two shots within the very small interval of time, which would be required for the gases from the second shot to meet the explosive mixture produced by the first, as it was swept round by the air current. But when the work was commenced at Harton, it was found that this difficulty could be got over by the use of an exploder, which is probably familiar to many here. It consists of a box covering a small coil fixed in front of a battery of permanent steel magnets and a keeper fixed in front of it. The keeper is maintained *in sitû* by a spring. A little bolt is securely fixed in the interior to prevent accidents from any careless handling of the apparatus. When that is taken out of the way, a handle is sharply pressed and produces a momentary disruptive current, so that the discharge of the shot may be effected at any desired distance in a fraction of a second; and two or more shots can be arranged by a very simple contrivance so as to be discharged in succession. This gave exactly what was wanted—the means of getting a series of shots representing the ordinary case of two or more shots in a working face, exploding in close succession, and so discharging one, two, three, four, or any number at any desired interval. The commutator used was of a very simple description.*

The tubes, AC, Fig. XVI., representing the shots, which Mr. May was good enough to have prepared, were on the whole as convenient and handy a contrivance as could be had. They simply consisted of pieces of iron tubing tapped with screws, which could be fastened tight up to the end of the box, and a little wood plug admitted of the detonating fuse being inserted through the breech-piece. With this contrivance it was possible to fire more successful shots in a given time, and after

* The apparatus was throughout under the management of Mr. J. Dunn, B.Sc.

very little experimenting it was ascertained that an interval of two or three seconds, varying a little with the different dusts, seemed to be what was wanted. So that one of the conditions necessary was fairly realised, *i.e.*, that the dust swept up by the explosion of the first shot should go round the second side of the box in time to be ignited by the shot fired from the second "gun."

It is perhaps unnecessary to give the details of all the experiments which were made in this apparatus, because they are far more clearly represented upon the table of observations (given in the Appendix No. 2), where it will be seen, that while with the clean box the flash observable through the glass windows extended only a very short distance, in nearly all the coal dust experiments the length of the flame was more or less increased — sometimes with a comparatively clear flame, which has been indicated by a firm line; sometimes with an appearance of sparks, which has been indicated by dotted and broken lines. It will not be necessary to enumerate the different kinds of dust which were used in these experiments, which included those from very representative specimens of different coal — Welsh, Derbyshire, Yorkshire, Scotch, Northumberland, and Durham. Although the authors have abstained from stating the names of the collieries from which they were obtained, it can be seen that in the character of these different varieties of "coal dust" (which seems to be rather generic than specific as a name) there were very wide variations indeed.

One object in these experiments was to find, if possible, some standard to which to refer with more or less certainty the ultimate results, so as to be able to answer the question which naturally would be the first to be asked—was there in these experiments anything which could be fairly called an "explosion" produced by firing a shot into about four or five cubic feet of these mixtures? In the first place, what is an "explosion"? If by an explosion is understood an action which brings the neighbours out of their houses to enquire what is happening, then certainly there was not an explosion at any time during these experiments. But if by an explosion is understood an action on a small scale which, magnified to a large scale, might produce what is usually termed an explosion, then the case is different. There is a wide difference between a soda water bottle filled with coal gas and air which produces a "puff" (which might be heard in the next room, or might not), and a large room full of coal gas and air. Here certainly the magnified result of the larger experiment is very different from that of the small one; and the same thing would seem to hold good in the experiments which gave the

results just described. That is, even in this small box, very bright flashes and explosions were produced, which, multiplied to the scale of an airway or a large gallery, would yield something which would deserve the name of an "explosion" proper.

In looking for such a standard to which to refer, it occurred to the authors that they might find one in a substance well-known to have produced *per se* explosions on a large scale, and using this on the same small scale might obtain some data for comparison. Such a substance presented itself in flour dust. It is well known that both in this country and in North America not only have serious accidents occurred, but that mills have been wrecked by the explosion of nothing but fine flour dust mixed with air.* The authors have been able, by the kindness of Messrs. Proctor and Sons, to obtain very representative samples of flour dust, to the results obtained from which attention is directed, especially to the line representing an explosion produced in the Harton apparatus with fine flour dust (Appendix No. 2, Plate XVII.), and to one which is just a little longer, representing an explosion produced with the finest coal dust from screens, which give a fair line for comparison. Now the effects of an explosion of flour dust, on a large scale, are perfectly well known, and comparing the effect obtained at Harton with flour dust, with the effects produced there by the explosion of coal dust under precisely similar conditions, an approximate idea of what an explosion of coal dust itself may do on a large scale is arrived at.

This is a summary of the principal results obtained at Harton Colliery, so far as the re-action of powder-shot gases on such a mixture, was concerned. Then, it was proposed to carry the thing a little further, in fact a few preliminary experiments were made as to whether it were possible by any means to get coal dust and air mixtures to fire at a naked light back into the box. Further research in this direction was rendered unnecessary by the results which were communicated to the writers shortly afterwards by a gentleman who does not desire his name to be mentioned, but who has had occasion to observe, both on a large and small scale, the effects of coal dust brought under certain conditions in contact with a naked light. The results of these observations are given in Appendix No. 3, as bearing on and confirming the results which have just been given, and some further experiments made by him are given in Appendix No. 4. The first occurrence to which this gentleman refers as having led him to examine the subject, happened so far back as 1871; a very considerable quantity of dust was accidentally

* See American Journal of Science and Arts. October, 1878.

thrown over some screens, came back over the flame from a fire, and burnt one man so severely that he was off work for something like fourteen weeks. Then came an occurrence especially interesting as bearing upon Mr. Galloway's theory with regard to the presence of gas being essential. In this case, which occurred in a stone-drift where, so far as could be ascertained, there was no possibility of gas being present, a certain quantity of fine coal dust, brought down by the air current and deposited in the neighbourhood, was dislodged by a blown-out shot. It was not only dislodged and blown up into a cloud, but it fired at the shot gas and did a very considerable amount of mischief. In the third case mentioned it is not quite so clear that the explosion was purely from coal dust, for it seemed possible that furnace gas might have been mixed up with it. Alluding to the comparative experiments which were made and tabulated in Appendix 4—they may be said to amount to this:—If a fair quantity of fine dry coal dust be taken (amounting in most of these experiments to between half-a-gallon and a gallon) and weighing from five to nine pounds, and showered from a sufficient height over a flame or fire, so that the fine coal dust is knocked up as it strikes the ground into a cloud, if that cloud was only a sufficiently large one, it would produce that which, if it was not an explosion, was at any rate a bright and very continued flash (though that flash, as might be expected, varied considerably with the conditions of the experiment), extending in some cases to a distance of 25 feet, and burning everything within its course.

Mr. FREIRE-MARRECO here reproduced this experiment in the Lecture Room, by letting various specimens of coal dust fall on to a gas burner, producing in each case a large volume of flame, varying with the different specimens of coal dust used; but even with dust taken from wagonways, which in every instance was necessarily mixed with all manner of foreign matter, the flame was very great.

He further stated that if this experiment was repeated with a couple of dozen different coals, after a little practice, the character of the coal of which the dust was composed could be fairly guessed from the kind of flash produced.

There are one or two other questions which suggest themselves at once, and which, although they are purely theoretical, bear upon this question and upon the conditions which will determine it. The writers were not very long at work before they found that it was perfectly easy

to fire shots in the immediate neighbourhood of coal dust without producing any perceptible effect. There were a rather complicated set of conditions to be satisfied, and it was necessary, in the first instance, to get some idea of what these conditions were. It is not in the least suggested that the data used represented absolutely the truth, but that they gave figures upon which there was a large margin to "play with." It is clear that with coal dust suspended in a current of air, it is necessary to consider, in the first instance, what the effect of the first access of the gas from the shot will be. There can be hardly any doubt that this would be like putting a match to an atmospheric coal-fire. The first effect would be to "carbonize" the coal, liberating a certain quantity of gas, etc., and, if the proportion of air present is sufficient, firing it. The practical question then becomes—will the heat evolved in the consumption of the gas from the coal dust be sufficient to carry on the combustion—to keep the fire burning in fact, and to spread through any length from the district in which the coal dust and air are first so acted on, and are the data obtained sufficient to indicate whether this would be so or not? In the first place, it is known with reasonable accuracy what the calorific values of average coals are; and if this is taken roughly at 13 or 14 lbs. of water boiled off at 100 degrees, it will not be very far wrong. This can be translated into a certain definite number of units, and if this is taken as the total heat producible by the coal dust, there is no doubt that that would be more than sufficient to propagate the action; but two other points require to be taken into consideration. First of all, the very act of gasification of those substances—the "carbonizing" of the gas manufacturer*—absorbed a certain amount of heat which it would be difficult to estimate accurately; but even if it be assumed that the carbon from the coal takes no share in the action—if it be assumed that the coal is simply coked by the shot-gases, and that therefore anything wanted to propagate the action must be got exclusively from the combustion of the volatile substances, the writers think that they can still say from these data that there will be left a certain margin of heat units, which, under favourable conditions, would be quite sufficient to propagate the action from one particle of coal dust to another, provided always that they were just sufficiently close to each other.

Here it may be remarked, there seems to be rather an essential difference between a solid combustible like coal dust or carbon mixed with air, and a mixture of two or more gases, as to the conditions

* Mr. Hardie, of the Newcastle Gas Co., informs us that about 2 cwts. of coke are required in practice to carbonize one ton of coal. It is evident that the actual units absorbed may be assumed to be much inside that figure.

required for explosive action. In the case of gas mixed with air the combustion can be stopped, or at least its rate of propagation checked and gradually diminished, until it could scarcely be called an explosion, by adding an excess of either of the constituents concerned in the re-action. If there is a perfectly explosive mixture of hydrogen and oxygen, it does not matter if it is diluted with air or with either H or O, a non-explosive point is at last reached; but although the action is largely diminished in force by a largely increased percentage of solid combustible matter, it does not check it to the same extent as if it was a gas.

Mr. FREIRE-MARRECO then proceeded to show by another experiment that the volatile portions of the coal might not be the only means of propagating the explosion. He did not say that the experiment might not be taken objection to, as not being absolutely analogous to coal gas and air, because what he was going to employ was a solid combustible carbon, which is more easily handled than coal dust, and, therefore, charcoal has been taken. True, coal dust might be heated to the same point, but not without coking; anthracite might be used, but it would do little more than give carbon, so that the experiment may as well be made this way. Mr. Marreco then took powdered charcoal and heated it to a dull red, and then shook it into a vessel containing oxygen, first in small portions at a time and then in a mass. In the first instance the finely divided charcoal showered down in small quantity caught fire, and burnt with a flash which might be easily mistaken for a combustible mixture of gases; in the second place, when the whole quantity was thrown into the oxygen, a more violent combustion took place, driving up a certain small but tolerably definite quantity of the carbon, which he stated, in some cases reached as far as the ceiling. The one thing required is to see that the carbon is fairly hot. Of course it need hardly be pointed out that this experiment could not be made with coking coal, because long before the coal could be got up to the point of burning it would at least be partly coked, and it would be no longer in a state of fine powder. The experiment was not at all a new one; it was one which has been in occasional use in lectures for a long time past for the purpose of showing that a solid could burn with a flash, but it was one which might well be used for the purposes of this illustration, and it seemed to him, under correction, that the principal interest of this experiment was that it proved clearly enough that if any notable quantity of the solid carbon remaining from the coal dust after coking by the shot gases took part in the re-action, that

that there would be a very much larger margin to work upon than if the 30 or 40 per cent. of volatile matter only, which is the outside that could be expected from ordinary "bituminous" coal, were considered.* It would be observed that the effect of shaking the hot dust in a very small quantity was to give nothing more than just a flash—a flash quite as bright as if a mixture of gas with the oxygen had been fired, and as the proportion was gradually increased, so long as there was any unconsumed oxygen, the results were better and better. Mr. Marreco then pointed out that the full quantity of red hot carbon used was far more than sufficient for the small quantity of oxygen which there was to work on, but he considered that the result, such as it was, gave a fair representation of a pit explosion on a small scale.

The authors, in conclusion, would like to call attention to one set of experiments which it appears to them to fit very perfectly into theirs. They are those of Mr. Hall,† who has experimented upon a much larger scale, but with what was in all essentials the same apparatus, for Mr. Hall's heavy powder shot fired at the end of a drift strewed with coal dust was really the same thing, on a much larger scale, as the boxes now described. It was a matter of very little consequence which of these sets of experiments was made first, for from the results now given it might have been expected that Mr. Hall's results would have been the same, multiplied in proportion to the difference between the magnitude of the experiments; or if they had started from Mr. Hall's experiments and reduced the dimensions of his drift to the dimensions of their box, they would have expected to get exactly the same results as they had got with similar dust.

APPENDIX No. 1.—TABLE OF OBSERVATIONS.

The table of observations inserted here gives the details of all the experiments made at Harton. The letters E^1, E^2, and E^3 indicate the first, second, and third east windows, and the letters W^1, W^2, and W^3 the first, second, and third west windows. When the shot A was fired, the flame was observed from the east windows; and when the shot C was fired, the flame was observed from the west windows. These results are shown together in a diagram given on Plate XVII.

* The analyses of the coal dust which has been used have not been completed, but it has been found that they had lost a rather large portion of the volatile matter which they might have been expected to contain—looking to the character of the seams from which they were derived.

† Transactions, Vol. XXV., p. 245.

BLE OF OBSERVATIONS.

Observations at Windows.		
Shot A.	Effect Prod	remarks.
E^3.	W^1.	
!	Flame	Spar lifted.
... ...	Flame	...
... ...	Flame	Flam
... ...	Flame	Flam g out of centre lid.
ame	Flame	Flam eavy smoke.
... ...	... ...	...
... ...	... ...	... l.
... ...	Flame	Flam own right off.
... ...	Flame	Flam bout box.
... ...	Flame	Flam Ea[1] window blown out by Ea shot.
... ...	... ...	... and all subsequent experiments. A few wadding
... ...	Slight flame ...	...
... ...	Flame	...
... ...	Flame	Flam
... ...	Flame	Flam t every joint of box.
... ...	Flame	Flam and smoke yet observed.
ame	Flame	Flam d through lids 3 feet above box, box generally
... ...	Flame	Flam y as last, flame through centre lid, smell of coking.
... ...	... ...	... y fall of brattice.
... ...	Flame	Flam e and smoke from centre lid and outlet.
... ...	... ...	... of box, brattice blown down, no effect.
... ...	Flame	Smal subsequent experiments—Fine powder.
... ...	Flame	... er.
... ...	Flame	Flam.
... ...	Flame	Flam xplosion on west side, fine powder.
... ...	Flame	Flam ke, more violent report, fine powder.
ame	Flame	Flam *d with red flame on both sides.*
all flame ...	Flame	Flam ke, heat intense.
all flame ...	Flame	Flam ke, heat intense.
ame	Flame	Flam oke.
ame	Flame	Flam experiment, guns pointed down.
... ...	Flame heavy ...	Flam *embling gunpowder, both* shots showed at west
... ...	Flame heavy ...	Flam
ame and smoke	Flame and smoke	Flam
... ...	Flame	Flam rement.
... ...	... ...	... s, centre lid slightly lifted, very little smoke.
oke and sparks	Flame	Flam ted, heavy brown smoke.
arks... ...	Flame	Flam id lifted, blue smoke, flame sharp, *resembling*
... ...	Flame	Flam lifted, sharp flash and report, little smoke.
oke... ...	Flame	Flam lifted, box shifted, heavy cloud of black smoke
		explosion yet observed.
ne	Do.	Do. ight-coloured flame, greyish smoke.
... ...	Do.	Do. . do.
... ...	Do.	Flam
... ...	Do.	Do. d dust.
t	Do.	Flam *plosion as heavy as* E^5.

To illustrate Professor A. Freire Marreco's and Mr. D.P. Morison's account of some recent experiments with Coal Dust.

Vol. XVIII PLATE XVI.

TEST BOX AND GENERAL ARRANGEMENT.

FIG. 1.

PLAN.

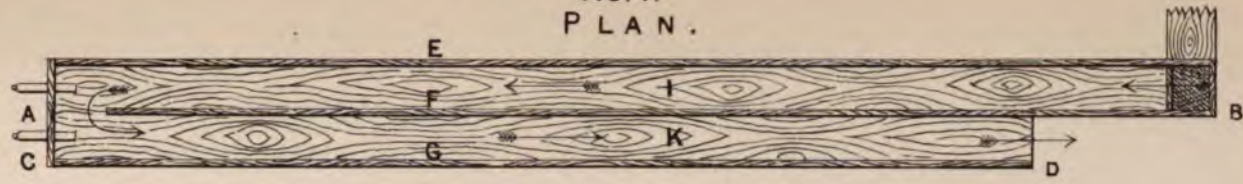


FIG. 3.

END VIEW A.C.

FIG. 2.

OUTSIDE VIEW.

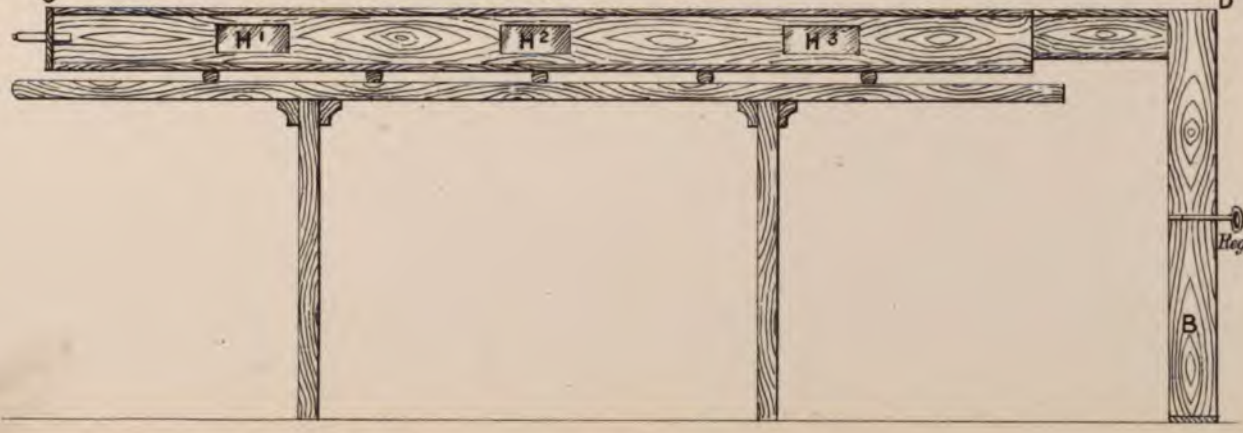
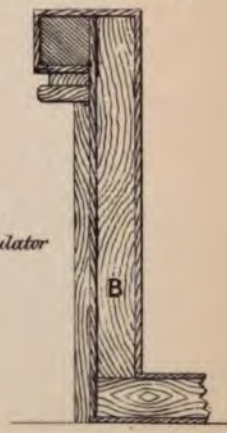


FIG. 4.

END VIEW B.D.



Scale 2 Feet – 1 Inch.

Proceedings N.E.I. of M. & M.E. 1878-79.

Andrew Reid, Newcastle.

TEST BOX AND GENERAL ARRANGEMENT.

FIG. 1.

PLAN.

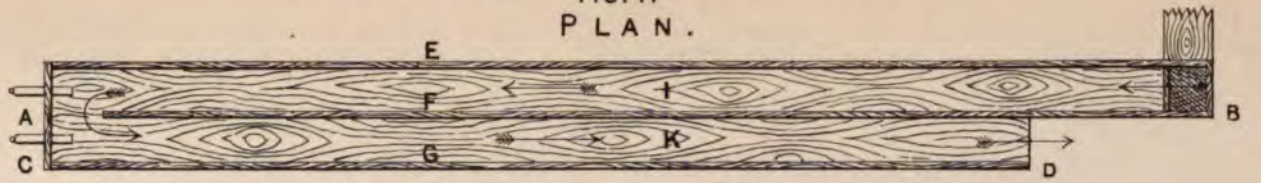


FIG. 3.

END VIEW A.C.

FIG. 2.

OUTSIDE VIEW.

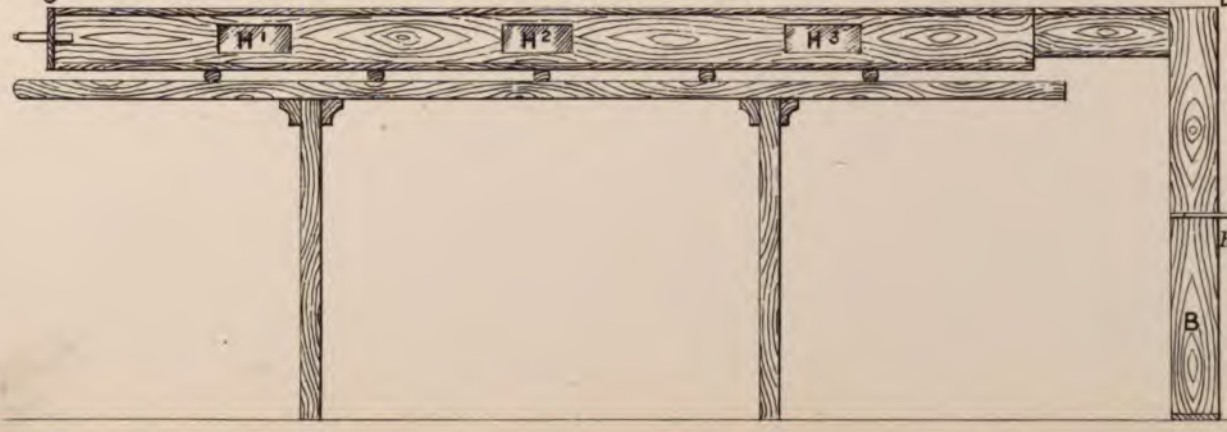
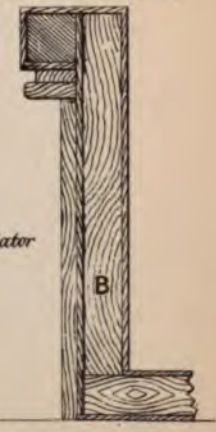


FIG. 4.

END VIEW B.D.



Scale 2 Feet – 1 Inch.

Proceedings of the E.I. of M. & M.E. 1878-79

APPENDIX No. 2.—PLATE XVII.

DIAGRAM OF LENGTH OF FLAME OBSERVED THROUGH WINDOWS IN SIDES OF BOX.

In order to show more clearly the relative effects of the various explosions, the diagram shown on Plate XVII. has been prepared, in which the length of the flames produced is shown by means of dark lines; E^1, E^2, and E^3 representing the east windows, and W^1, W^2, and W^3 representing the west windows. The lines representing the two shots fired in each experiment are bracketed together, the upper line representing the flame produced by the shot A, and the lower line that produced by the shot C.

APPENDIX No. 3.

AUTHENTICATED CASES OF COAL DUST EXPLOSIONS.

There have been four well-authenticated cases of coal dust explosions at a colliery, the name of which it is unnecessary to give, within recent years, but with the exception of the last none have been particularly recorded. Eye witnesses of each, however, are still resident on the colliery, and from them the following particulars have been obtained:—

FIRST.

This took place towards the end of 1870, or the beginning of 1871, upon screens, under the following circumstances. Deals were fixed over the gaslights upon the screens to prevent the rain-water trickling through the heapstead from falling on them. One very stormy day these blew loose, and a man was sent to pull some of them down. While so engaged a quantity of dust fell into the flame below and exploded, severely burning one of the screenmen, who was off work fourteen weeks in consequence. The flame is described as rising as high as the heapstead would permit it, and being very hot. Another man, who was working on the next screen, felt the heat very strongly, but was not actually burnt.

SECOND.

Towards the end of 1872 some workmen were engaged shooting out refuge holes in a stone drift near the down-cast shaft, where a large amount of fine coal dust was deposited after coming down the shaft with the air current. Two of the men drilled a hole about 15 inches long, directly horizontal into the side, giving it no vantage whatever. As a matter of course the charge blew the stemming, and *the flash ignited*

the cloud of dust raised by the shock. A considerable explosion resulted, which at the time caused some consternation, as most of the men attributed it to gas, although there cannot be the slightest doubt as to the dust being the cause of it, the explosion being in the main intake to No. 3 Pit where from 50 to 60,000 cubic feet of air passed per minute.

THIRD.

This occurred at bank some time during the spring of 1876, but for some unexplained reason was not reported at the time. The circumstance was this: While one of the firemen employed at No. 2 Pit boiler was engaged in picking his fire, a boy turned a tub of coals into a sort of hopper at the back of the boilers from which the firemen obtain their supply of coals; this being almost empty at the time, a great cloud of dust was raised, which, coming out of the small archway through which the coals pass, travelled towards the boiler fire. It there exploded and burnt one of the men, who was off work a few days.

FOURTH.

This occurred on the screens, on July 19th of the present year. Some coal dust, lying on a sort of "picture" over one of them, suddenly fell off. The dust was ignited by the gas jet burning beneath, and an explosion resulted. The flame was bright and very hot. The flash reached the heapstead and there *dislodged some more dust, which again exploded.* Had the two screenmen not thrown themselves off the screen into the waggon at some risk of their necks, they would have been severely burnt, but as it happened they got off pretty lightly, though one of them was unable to work for about three weeks. Some of their clothes, hanging above their heads, were so burnt as to be useless.

After this last affair happened, some experiments were made on the explosive power of dust, the results of which are appended hereto, and though rude in form, clearly show that under certain circumstances a cloud of coal dust will explode with considerable violence.

In the above experiments the dust was dropped on to the ground by the side and partly on the top of a small fire kindled about eighteen inches above the level of the surface. As the cloud of dust rose from the ground the wind carried it right into the fire. It was found that *unless the fire was flaming freely* it did not ignite the dust so well. No. 11, 12, and 13 experiments were tried with dust almost as pure as that obtained from bank; all the other underground dust was more or less mixed with foreign matter.

APPENDIX No. 5.

FURTHER EXPERIMENTS TO ASCERTAIN THE EXPLOSIVE POWER OF COAL DUST, MADE IN THE COUNTY OF DURHAM IN AUGUST, 1878.

No. of Experiment.	Quantity of dust Employed.	Where Obtained.	Result.
	GAL.		
1	1	Intake to No. 1 boilers, underground, near downcast shaft.	Heavy explosion, extending over an area of 20 ft. in diameter; flame, very red and hot; made a loud rushing sound.
2	½	Do. do.	Wind carried dust away from flame, and did not explode.
3	½	Do. do.	Do. do.
4	1	Do. do.	Exploded, though slightly.
5	1	Do. do.	Did not come in contact with flame.
6	1	Main coal intake, near No. 2 shaft.	Dust falling into flame extinguished it; did not explode.
7	1	Do. do.	Do. do.
8	1	Do. do.	Do. do.
9	1	Do. do.	Flame removed so that no portion of dust fell direct into it; a small explosion took place, but it was very feeble.
10	1	From under low pit screens.	Heavy explosion, similar to No. 1, but more violent; flame rose fully 20 ft. high.
11	1	Do. do.	Same as last, though perhaps heavier.
12	1	Do. do.	About the same as last.
13	1	Do. do.	This was a magnificent explosion; cloud of smoke and flame rose fully 30 feet, and the flash set fire to chips, etc., over an area of 25 to 30 feet in diameter; in appearance and sound it resembled No. 1, though much exaggerated.
14	1	The unexploded dust lying on the ground below the flame.	Did not explode.

In the experiments given in Appendix No. 4 the dust was dropped on to the ground from an elevation of 12 feet; both as it fell (with the exception of No. 9) and as it rose again, the cloud came in contact with the flame of a gas jet, issuing from a half-inch burner. It is not easy to make any comparison of the force of the explosion, but Nos. 1, 10, 11, 12, and 13, of these experiments, and Nos. 7, 8, and 11, of those in Appendix 5, would be equal in appearance to say 4 or 5 lbs. of loose powder set fire to on the surface, though that is probably an under estimate.

Mr. FREIRE-MARRECO then stated that he was led to think that while it was impossible to get on this scale anything which can, strictly speaking, be called absolutely an explosion from coal dust, a result could, nevertheless, be obtained which is capable of doing considerable damage, and at any rate capable of lengthening to an indefinite extent the flame from the blown-out shot; and that it is not altogether improbable under certain conditions—these conditions, however, he could hardly as yet properly define—that such a mixture may be made which should not require the start from the gases of a blown-out shot, but which should require only the comparatively small initiatory stimulus which is represented by the match which lights a fire. That was the thing which they had yet to work out. There could be hardly any doubt about it, that they could lengthen out these shots—or rather their flame—by the very coal dust which they knock up for themselves. So that it may be said that they lay their fire and light it too. But the question had still to be worked out, whether coal dust and air can, under certain conditions, be made to reproduce at a very distant point the phenomenon which was described in Appendices Nos. 4 and 5. He could not say, but his own belief was that it could be done, and that they had only to find out the necessary variations of conditions to do it.

Mr. A. L. STEAVENSON remarked that several years ago he remembered an accident which occurred from the effects of a blown-out shot, which showed the great length the flame from these shots was projected. Before the shot was fired the deputy had carefully examined the place and found it entirely free from gas. The place was driven up about ten yards, across the end of the bord an iron tub was standing, and behind this tub a man was sitting without his shirt, as he thought, in a place of safety; but after the explosion of the shot he was found to be so severely burnt that he died from the effects of the injuries he had received. On examining the tub distinct marks of the pellets of the blasting powder were discovered, showing that the shot had fired from the lower or inner

end and had projected some unburnt powder as far as the tub, exemplifying in the most striking manner the effects of a blown-out shot at the distance of 10 yards, and showing that the effect of shots was far more powerful than was generally allowed. In the Cleveland ironstone district, of course, there was no coal dust, and although gas was at times to some extent present, yet practically it might be considered as entirely absent where blasting was being carried on, yet in these ironstone mines he had seen the flame from blown-out shots extend as far as fifteen yards. At the Paris Exhibition a gentleman had shown him an invention for preventing flame issuing from the explosion of a cartridge, by tamping the shot with water enclosed in a sort of cartridge, which was placed over the powder, and the water was expelled with the explosion. He could not say how far this would effect the object desired, but he was assured by the inventor and patentee that it answered perfectly. In conclusion, he had much pleasure in proposing a vote of thanks to Messrs. Marreco and Morison for the very valuable information they had given.

The PRESIDENT seconded the motion, which was unanimously carried.

Mr. LINDSAY WOOD wished to know from what part of the mine the coal dust had been obtained for the purposes of the experiments. He had known small quantities of coal dust fire, or, as it were, explode, but then it was in parts of the colliery where the dust was comparatively pure coal, and not mixed with the fire clay and other impurities trodden up by the ponies which constitute so large a portion of the dust in the working part of the pit.

Mr. FREIRE-MARRECO said, in reply, that he did not consider that absolutely pure coal dust gave necessarily the strongest possible explosion. They had used dust from the wagonways that was very considerably mixed with foreign matters, such as fire clay and horse dirt, and which gave very considerable results. But one of the strongest effects obtained was from dust taken from a stone drift way where it had been deposited by the current of air.

Mr. MORISON—This dust was exceedingly fine.

Professor HERSCHEL said that he did not consider it necessary that the dust should be so impalpably fine to cause it to explode. He had experimented by shaking up the ordinary flour of commerce in a dry state in a box containing a light, and had succeeded in producing an explosion that had lifted the cover of the box. It is true he had only succeeded once in this experiment, but it showed that the excessive fineness of the dust was not absolutely necessary to produce an explosion.

Mr. COCHRANE, in reply to a question, said that there had been explosions from single shots.

Mr. MORISON explained that the reason they had second shots was because the coal dust had to be disturbed, and they found that in no way could it be so easily mixed with the air in the box as by the firing of a shot; and, after repeated experiments, they found that by exploding the shots rapidly one after another (which they were enabled to do by means of electricity) the second shot went off while the coal dust was intimately mixed with the air in the box, but in all cases the length of the flame resulting from the first shot was recorded in the table, and they could judge for themselves of the relative effects of the shots.

Mr. STEAVENSON asked if they might not have mistaken the explosion of grains of powder unconsumed in the barrel of the cannon as they passed by the windows for the explosion of coal dust?

Mr. MORISON stated that the charge used was not the quantity usually put in a shot in a mine, but only a much smaller quantity, one, in fact, reduced in proportion to the area of face of the model box as compared with an ordinary working place, and thus there was a very small chance of any of the powder being unconsumed after it left the chamber of the cannon.

The PRESIDENT asked if they had put any valves upon the top of the box to ascertain if there was any pressure inwards or outwards during the time of the explosion?

Mr. FREIRE-MARRECO explained that they had endeavoured to ascertain if there had been any inward or outward pressure during the experiment (for he thought that there would be both) by means of a recording water gauge, but owing to the water oscillating so much they were obliged to discontinue its use; however, they might possibly ascertain this by further experiments in the laboratory.

Mr. MORISON said that they had apertures in the top of the box, through which the coal dust was inserted, and that these were covered with boards secured by weights, and in heavy explosions these were sometimes blown off, and when so, it was invariably those apertures furthest from the shot that were so disturbed, probably from the effect of the fresh air rushing in after the explosion.

The PRESIDENT stated that he knew several cases where men had been burnt under circumstances similar to those described by Mr. Steavenson, and he had no doubt that the experience of many other members would enable them to confirm his testimony when the paper, after having been printed and in the hands of the members, was brought up for discussion.

The meeting then separated.

VISIT TO BROWNEY COLLIERY.

NOVEMBER 21ST, 1878.

ABOUT eighty members of the Institute availed themselves of the kind invitation of Messrs. Bell Brothers, to view this colliery, and examine the apparatus for saving labour in the manufacture of coke—the invention of Messrs. Bell, Harle, and Clough—the Schiele fan, and the many objects of interest to be seen in this admirably laid out colliery.

The visitors were conveyed to the colliery by the ordinary trains, extra carriages for their accommodation having been kindly provided by the officials of the North-Eastern Railway Company. They were received by Mr. A. L. Steavenson, the chief engineer to the company, who courteously explained the many objects of interest there were to examine.

The apparatus attached to the coke-ovens for saving labour is fully described at page 127, Vol. XXVII, of the Transactions. As adapted to this colliery, it is made to serve 47 ovens of the ordinary beehive form. The tray or belt is about 200 yards long, and runs the whole length of the ovens, immediately below the oven doors. It is driven by a single engine, 15½ inches diameter, and 3 feet stroke, which is considered large enough not only for the work it is at present doing, but also to drive the apparatus, which will shortly be applied to the rest of the ovens, 150 in number, since at present the actual indicated horse-power required is only eight.

The average charge of each oven is 6 tons 10 cwts., and this yields about 4 tons of coke. The ovens are drawn three times a fortnight. Previous to the application of this apparatus the men were paid 1s. 9½d. per oven for drawing alone. The drawing now costs 1s. 2d. per oven.

The filling, which formerly cost tenpence per oven, is now done without manual labour. Each man now draws four ovens in a day of eight hours, while formerly he could only draw two; and the cost of labour has altogether been reduced more than one-half.

The whole of the heat passing from the coke-ovens is utilized in heating the boilers upon the colliery. These are ten in number, 60 feet

long, 5 feet in diameter. There are two chimneys, each 130 feet in height, and so perfect is the combustion that on the clearest day not a particle of smoke can be seen.

The coal used for supplying the ovens is a mixture of one-third from the Busty seam and two-thirds from the Brockwell seam, the former seam lying at a depth of 80 fathoms, and the latter at a depth of 100 fathoms. The whole of the coal which does not pass through the screens is crushed by one of Carr's disintegrators before being coked.

The visitors were conducted down the shaft to view one of Schiele's ventilators, in the Brockwell seam, at a distance of 50 yards from the shaft. The diameter of the fan is 7 feet, and at the time of the visit was making about 200 revolutions per minute; it is driven by a horizontal engine 9 inches diameter and 12 inches stroke, working at 100 revolutions per minute. The quantity of air delivered at these velocities is 35,000 cubic feet per minute. The fan can, however, be so driven as to produce a much greater effect.

Mr. STEAVENSON stated that the colliery had been commenced in the early part of the good times. The Hutton seam was first reached at a depth of 36 fathoms; and although the quality was not all that could be desired, yet as the demand for coal was so great, it was determined to stop sinking and to work the coal, continuing the sinking in the other pit to the west. Here, at a depth of 60 fathoms, they met with basalt, not a mere dyke, but a compact horizontal layer 19 feet thick, of an exceedingly hard character, so much so that four months were occupied in sinking through it. Then the Busty seam was reached at a depth of 80 fathoms, and ultimately the Brockwell at a depth of 100 fathoms. The Busty seam is 4 ft. 3 in. thick, of fair, average quality, with a small band of clay. The Brockwell is about 3 ft. thick.

After viewing the colliery, the visitors were assembled in one of the buildings, where luncheon was provided by the owners; and after a vote of thanks had been given to Messrs. Bell Brothers for their kind invitation, and to Mr. A. L. Steavenson for his courteous reception, the members separated.

PROCEEDINGS.

GENERAL MEETING, SATURDAY, DECEMBER 7TH, 1878, IN THE WOOD MEMORIAL HALL.

G. C. GREENWELL, ESQ., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last general meeting, and reported the proceedings of the Council.

The following gentlemen were elected:—

ASSOCIATES—

Mr. WILLIAM PRICHARD, M.E., Navigation and Deep Duffryn Collieries, Mountain Ash, South Wales.

Mr. JOHN THOMPSON, Heworth Colliery, Heworth.

The following were nominated for election at the next meeting:—

ORDINARY MEMBER—

Mr. TOM PATTINSON MARTIN, Colliery Manager, Allhallows Colliery, Mealsgate, Carlisle.

ASSOCIATE—

Mr. LOUIS CLOVIS, 1, Borough Houses, Gateshead-on-Tyne.

STUDENTS—

Mr. A. B. BLAKELEY, Hollyroyd, Dewsbury.

Mr. H. CHILD, Whitkirk, near Leeds.

Mr. JOS. WM. PATTISON, Londonderry Offices, Seaham Harbour.

Mr. SEPTIMUS H. HEDLEY, Londonderry Offices, Seaham Harbour.

Mr. THOMAS SMITH, Leadgate, County of Durham.

The President said that the Council had decided that Mr. J. D. Kendall's paper, "On the Hematite Deposits of West Cumberland," should be taken as read, and discussed at a future meeting.

THE HEMATITE DEPOSITS OF WEST CUMBERLAND.

By J. D. KENDALL, C.E., F.G.S.

PART I.—INTRODUCTORY.

Perhaps there is no district of equal importance in the whole of the British Isles which has received so little attention from men of science as the hematite district of West Cumberland. As far as the author is aware, with the exception of one or two papers of his own, there is not in the whole literature of geology and mining a notice of these deposits which extends over more than a page or two. That being so, it seemed to be a very fit subject to bring before this Institute. That it has not been dealt with by some of the members before, is somewhat surprising, seeing that so many of them are now more or less directly interested in the iron trade, the recent rapid development of which is in a great measure due to Bessemer's discovery in connection with hematite. This neglect of the subject cannot be due to its uninteresting nature, for so long as such questions as—How did the deposits originate? What is their age? and Where are they to be found?—remain unanswered, the subject can never be uninteresting. Perhaps it has been thought to be a matter more for the consideration of the geologist than the mining engineer. But that is not so, for if not the whole, clearly the last of the above questions very deeply affects the mining engineer.

It is the intention of the writer to deal with each of the above questions, but to confine the present communication to the two first.

As in science generally, so in reference to questions such as the above, the more those facts are known which are to be discovered only by observation, the more easy it will be to arrive at facts by inference, and consequently the sooner it will be possible to see an explanation of the phenomena under investigation. It is proposed, therefore, in the consideration of these questions to introduce as many facts of observation as possible. Many of these observations will no doubt be found quite new,

even to those who are working the deposits day by day, whilst many more of them have not been previously recorded.

That part of West Cumberland in which these hematite deposits occur may be roughly described as a belt of country, of varying width, extending along the sea coast from Millom on the south to Whitehaven on the north, a distance of about twenty-nine miles; its greatest width being about eight miles. (See Plate XVIII.) Along the landward edge of this belt stand some of the western mountains of the lake country, which vary in appearance according to the nature of the rocks of which they are formed, being sometimes of a rough and rugged outline, at others smooth and regular. Between this mountainous tract and the sea, the ground is low and gently undulating, seldom rising above 400 feet, and being mostly below the 150 feet contour.

The hematite deposits hitherto worked occur in the centre and at the extreme ends of this belt; those in the north being about Kelton, Salter, Winder, Frizington, Cleator Moor, and Bigrigg, and those in the south at Hodbarrow and Water Blean. The deposits in the central part of the belt being in the hills about Eskdale.

The geological systems represented in the district are not numerous, but they are very well developed. Their relation to one another will be best understood by reference to Fig. 1, Plate XXI., which shows the various rock groups making up each system, as well as where they conform and where they are unconformable.

The extent of these rock groups on the surface is shown on Plate XVIII. Plates XIX. and XX. are enlargements of the north and south ends of the district respectively. They show the geological structure more in detail; these maps render unnecessary any written description of the extent of the various rocks, but it will be needful to say something as to their lithological constitution and their stratigraphical relations. This will be done as briefly as possible, only in the case of some of the rock groups more intimately connected with the subject under consideration it will be requisite to go somewhat into detail before some of the arguments to be brought forward hereafter can be fully appreciated.

Granite is found only at one point, as shown at *g g*, Plate XVIII. It is known as the Eskdale granite, from the fact that it is mainly found in that locality. Its colour varies from grey to red, according to the colour of its felspar. Several deposits of hematite have been worked in it, but only one to any extent, that is the vein in Nab Gill, near the Boot, in Eskdale. The composition of this rock, as given in the "Survey Memoir of the Lake District" (northern part), is as follows:—

Silica	73·573
Alumina	13·750
Lime	1·064
Magnesia	·396
Potash	3·512
Soda	4·315
Ferrous oxide	2·103
Ferric oxide	·615
Phosphoric acid	·012
Sulphuric acid	——
Carbonic acid	trace
Water (loss on ignition)	·660
	100·000

SKIDDAW SLATE forms much of the high ground near Ennerdale, in the N.E. portion of the district, and also the mountain of Black Comb in the south. (Plate XVIII.) It may be looked upon as the basement rock of the district. It consists of bluish, greenish, and purply-grey mudstones, and greyish grits, which are sometimes spotted with purple or brown. Neither of these rocks are much used for economic purposes, partly on account of the ease with which the atmosphere and other meteoric agencies act upon them, and partly on account of their being so much split up by joints. Their thickness is uncertain, but has been variously estimated at from 5,000 to 10,000 feet. Owing, however, to the great similarity of the beds, and the consequent difficulty of detecting faults, their real thickness is probably less. For the same reason the succession of beds has not yet been properly ascertained, so that it is impossible to be quite sure of the horizon of many of them. They are generally inclined at high angles, which vary both in direction and amount. In ten square yards of ground they have been seen to dip to the four principal points of the compass, at angles with the horizon varying from 45 to 80 degrees. They are, moreover, much split up by joints, which range themselves into two sets—one set running about 15 degrees N.E. and S.W., and the other about 37 degrees N.W. and S.E. Sometimes the dip and strike of the strata correspond with one of these sets of joints. The rocks have then a flaggy appearance; but more generally the beds are intersected by both sets, in which case the rocks, owing to their thin bedding, have a very broken appearance. Hematite has been found in this group at several places, but in workable quantity only at Kelton Fell and Knockmurton.

The composition of the Skiddaw Slate as it exists at Red Pike, not far from Knockmurton, is given in the "Lake District Memoir" as follows:—

Silica	54·480
Alumina	20·720
Lime	1·624
Magnesia	1·946
Potash	3·203
Soda...	6·217
Ferrous oxide	8·188
Ferric oxide	·988
Phosphoric acid	·569
Sulphuric acid	trace
Carbonic acid	trace
Carbonaceous matter	·361
Water	1·704
	100·000

Borrowdale Series.—The volcanic lavas and ashes of this series, usually known as the Green Slates and Porphyries, form the remaining portion of the high ground in the eastern side of the district. It is through these rocks that the Eskdale granite last rises in its passage to the surface, as shown in Plate XVIII. and Plate XXI., Fig. 1. Hematite has been found in the series at a great many places, but only in very small quantity, so small, indeed, that it has never, so far the writer knows, been worked.

Coniston Series.—These consist of Coniston Limestone, Coniston Grits, and Coniston Flags, and occupy but a small area in the southern part of the district. The limestone formation occurs sometimes as one solid bed of limestone, at others it is found in somewhat thinner beds, which are interstratified with limey shales. It is generally of a deep blue-grey colour, and some of the more shaley portions weather very much. Usually it is inclined at very high angles, sometimes being nearly on end. The grits and flags are of a very hard and durable nature, and are much used for building purposes. They occur alternately throughout the upper part of the series. Hematite is not abundant in these rocks, but in the limestone at Water Blean a deposit has been worked for some time. The writer is not aware that any has been found in the grits and flags.

Carboniferous Limestone.—This is the most important group of rocks in the district, as in it are found those immense deposits of Hematite through which the district has become so famous. It rests transgressively on the denuded edges of the Silurians, lying sometimes on the Skiddaw Slate, as in the northern part of the district. (Plate XXI., Fig. 2.) At other times it may be found upon the Borrowdale or Coniston Series, as between Silecroft and Millom.

It dips to the west or north-west, at angles varying from 12 to 30 degrees with the horizon, and may be said generally to consist of alternations of limestone, sandstone, and shale. The limestone is the most fully developed, and in the northern part of the district occupies about two-thirds of the whole group. From the correlation of a great number of sections which have been obtained, either by boring or sinking between Rowrah and Egremont, the writer considers that it may be divided into six distinct beds, as shown in Plate XXI., Fig. 3.

The thicknesses of these limestone beds are as follows:—

	Ft.	Ft.
First or Langhorn Limestone (one solid bed of Limestone) ...	36 to	60
Second do. do. ...	15 to	24
Third or Clints Limestone (split up variously in different parts of the district by minor beds of shale, etc.) ...	250 to	330
Fourth Limestone do. do. do.	50 to	70
Fifth do. do. do. do.	58 to	70
Sixth or Bottom Limestone do. do.	90 to	135

As a rule, the First Limestone is thicker about Bigrigg than in the Winder locality; but, on the other hand, the Third Limestone is thicker at Winder than about Bigrigg. The other beds do not vary much in the two localities. The greatest thickness known to the author as having been proved at one point is 758 feet; this was at Winder Gill, with the diamond rock borer. The whole six beds were passed through, the last one resting upon the Skiddaw Slate. At Bigrigg the whole of the beds have not yet been passed through at one point, but by adding together different sections the thickness of the Limestone Series there is found to be about 620 feet.

The strata separating the various beds of limestone, as shown by the darker bands in Plate XXI., Fig. 3, consist of alternations of shale and sandstone, and sometimes a thin layer or two of limestone; but these beds follow no regular order in the different parts of the district. This is illustrated by the thick mass separating the Second and Third Limestones. About Winder this intermediate bed consists mainly of dark shale. At Bigrigg it is nearly all sandstone, whilst between these two places it is made up of both shale and sandstone in varying proportions, the sandstone becoming less and the shale thicker as Winder is approached.

At the south end of the district, that is about Millom, these rocks have not been very well proved; but they seem to follow the form of development of the Furness rocks rather than of those just described. There the group consists of four principal divisions: the basement conglomerate,

Silica	54·480
Alumina	20·72
Lime	1·
Magnesia	
Potash	
Soda...	
Ferrous oxide	
Ferric oxide	
Phosphoric acid	
Sulphuric acid	
Carbonic acid ...	
Carbonaceous matter	
Water	

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...y large deposits occur in the

BORROWDALE SERIE... ...n the north it has been found in

usually known as the ... of more or less importance have been,

portion of the hig... ...them. A few of these deposits may perhaps

through these ... ...oned here.

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has been f... ...First or Langhorn Limestone there are (1) The Winder Gill

quantity ...deposit; (2) The Flat ore at Agnes Pit; (3) The Parkside and Crossgill

work... ...deposit; (4) The Crowgarth deposit; (5) The top deposits at Bigrigg;

and (6) part of the Woodend deposits.

In the Second Limestone there is the second deposit at Bigrigg.

In the Third or Clints Limestone there are (1) Wyndham Pit deposit; (2) some of the Woodend deposits; (3) some of the Montreal deposits; (4) the deposit worked by the Mowbray Co.'s No. 2 Pit; and (5) the Salter Hall deposit.

In the Fourth Limestone there are (1) The Salter and Eskett Park No. 7 Pit deposit; (2) the upper deposit worked by the Crossfield Co.'s No. 3 Pit.

In the Fifth Limestone there is the deposit worked by the Salter and Eskett Park Co.'s No. 5, 8, and 9 Pits.

In the Sixth or Bottom Limestone there are (1) lower deposit worked by the Crossfield Co.'s No. 3 Pit; (2 and 3) the deposits worked by the Nos. 10 and 11 Pits of Messrs. Bain & Co.; (4) lower deposit in up side of fault at Mr. Postlethwaite's Eskett Pits.

From this it will be seen that there is a very wide difference in the *geological* level of the deposits. Owing, however, to the tilted position of the limestone, the way in which it is dislocated by faults and the extent to which it has been denuded, this difference in geological level does not affect their *absolute* level, as many of the deposits in the lower beds are quite as

usually considered as belonging to the Old Red Sandstone; then a thick mass of red limey shales, with thin beds of limestone, above which there is a great mass of limestone, with irregular partings of red and grey shale; and the group is terminated upwards by a considerable thickness of black Yoredale shales, with which, in the lower part, are intercalated a few beds of limestone, and in the upper part some beds of sandstone. Its total thickness has been proved to be over 2,200 feet.

In Millom, only the Thick Limestone of Furness has been proved so far, but there is every probability that both the underlying shales and the basement conglomerate exist there, as they have been found on the opposite side of the Duddon Estuary.

As already stated, hematite is found very abundantly in those rocks. In the southern point of the district two very large deposits occur in the Thick Limestone at Hodbarrow, and in the north it has been found in each of the six beds, and deposits of more or less importance have been, or are now being worked in them. A few of these deposits may perhaps be conveniently mentioned here.

In the First or Langhorn Limestone there are (1) The Winder Gill deposit; (2) The Flat ore at Agnes Pit; (3) The Parkside and Crossgill deposit; (4) The Crowgarth deposit; (5) The top deposits at Bigrigg; and (6) part of the Woodend deposits.

In the Second Limestone there is the second deposit at Bigrigg.

In the Third or Clints Limestone there are (1) Wyndham Pit deposit; (2) some of the Woodend deposits; (3) some of the Montreal deposits; (4) the deposit worked by the Mowbray Co.'s No. 2 Pit; and (5) the Salter Hall deposit.

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In the Fifth Limestone there is the deposit worked by the Salter and Eskett Park Co.'s No. 5, 8, and 9 Pits.

In the Sixth or Bottom Limestone there are (1) lower deposit worked by the Crossfield Co.'s No. 3 Pit; (2 and 3) the deposits worked by the Nos. 10 and 11 Pits of Messrs. Bain & Co.; (4) lower deposit in up side of fault at Mr. Postlethwaite's Eskett Pits.

From this it will be seen that there is a very wide difference in the *geological* level of the deposits. Owing, however, to the tilted position of the limestone, the way in which it is dislocated by faults and the extent to which it has been denuded, this difference in geological level does not affect their *absolute* level, as many of the deposits in the lower beds are quite as

near to the surface as those which occur in the higher beds. For instance at Crossfield and Todholes deposits are found in the Bottom Limestone so near the surface that they have been worked by "open cuts," and, as will hereafter be seen, deposits of ore are not unfrequently found on the same absolute level (but on opposite sides of a fault), which are in totally different beds of limestone.

MILLSTONE GRIT occurs only in the northern part of the district. It consists of alternations of shales and sandstones, which are very variable in thickness and not very persistent. The bottom bed—that resting on the first Limestone—is, however, an exception, as, so far as the writer knows, it is invariably a sandstone, with sometimes a thin parting of shale below it. At Parkside these rocks have been proved to be over 450 feet thick. They seem, however, to be much thinner as the distance from the hills increases. At John Pit, in the Harrington Coal-field, the Carboniferous Limestone was proved at thirty fathoms below the Udale Band, so that if the grits are supposed to have been immediately below that seam, their thickness could not possibly have been more than 180 feet. At Bigrigg their greatest known thickness is about 250 feet.

Very little hematite occurs in these rocks, although in places it has been worked in connection with these deposits in the Top Limestone. From these latter deposits it runs in thin strings into the bottom bed of sandstone which forms the base of the grits.

THE COAL-MEASURES are divisible into two parts, which are unconformable to one another, as shown in Plate XXI., Fig. 1. First—The lower portion is made up of alternations of sandstone and shale of the prevailing dark colour, amidst which occur numerous bands of fire clay, coal, and clay-band ironstone. The greatest thickness of this portion of the Coal-measures is about 1,100 feet, in which there are, at least, twenty-six seams of coal. It forms by far the largest portion of the Coal-measures, and may be looked upon as the productive part of the Cumberland Coal-field. Second—The upper portion of the series, called the Whitehaven Sandstone, consists of alternations of reddish and dark shales, and purple, grey, and white sandstone. With the dark shales there is sometimes a little coal. The sandstones usually contain a number of plant-like remains and clayey nodules, both of which are highly charged with peroxide of iron. In the beds of sandstone near the base of the formation, grains of white quartz are occasionally found as large as a good-sized pea, which are in some cases scattered sparsely through the sandstone, whilst in others they are so closely packed as to give it the appearance of a breccia. In some places between the interstices of the rock there is a considerable

quantity of specular iron in minute scales. In the same beds nodules of compact hematite are met with. Like the grits, the Whitehaven Sandstone seems to thicken in an easterly direction. At Croft Pit it is only 171 feet. At Bigcroft it is 239 feet thick.

The extent of the unconformity that exists between the two parts of the group may be judged from the fact that at Croft Pit the Whitehaven Sandstone overlies the whole of the lower Coal-measures, whilst at Rowrah it is down upon the Millstone Grit. Plate XXII., Fig. 1, is a section between Croft and Wreah Pits, in the Whitehaven Coal-field. At the former pit the seam of coal known as the Main Band is 475 feet below the Whitehaven Sandstone, whilst at Wreah Pit, only two-and-a-quarter miles away, it is not more than 60 feet below.

In this group hematite has only been found in workable quantities at Millyeat, in the Whitehaven Sandstone. Its existence in those rocks has a very important bearing on much that has hereafter to be said, so that it is proposed to give one or two sections to show the succession of beds and the exact horizon on which the hematite occurs. Unfortunately information of that sort is very scarce where it would be most desirable to have it. The only section that has come to the author's knowledge, obtained at one point, is the journal of a bore-hole, that was put down, in search of this hematite, between Millyeat and Weddiker. It is as follows:—

No. I. SECTION.

	Fms.	Ft.	In.	Fms.	Ft.	In.
1.—Superficial deposits		3	0			
2.—Breccia	10	3	0	11	0	0
3.—Grey sandstone	1	5	0			
4.—Red shale	2	1	0			
5.—Grey sandstone		2	0			
6.—Red shale	9	0	8			
7.— Do. with iron ribs			4			
8.— Do.	7	0	10			
9,—Sandstone		2	6			
10.—Red and white shale		1	3			
11.—Sandstone		2	6			
12.—Red shale	3	0	10			
13.—Sandstone		2	0			
14.—Red sandy shale	1	2	4	37	3	3
Thickness of Whitehaven Sandstone passed through ...				26	3	3

At Croft Pit these rocks were passed through immediately below the Magnesian Limestone. The section is as follows:—

No. II. SECTION.

Magnesian Limestone.	Fms.	Ft.	In.
1.—Soft red sandstone		1	6
2.—Red shale with layers of sandstone		2	6
3.—Red sandstone	7	0	6
4.—Soft red shale			6
5.—Red shale	8	4	0
6.—Reddish grey sandstone	4	5	9
7.—Lumpy red sandstone, speckled with white			9
8.—Blue shale, speckled with coal			9
9.—Red soapy shale	2	1	0
10.—Black shale, with a small appearance of coal under it ...		1	0
11.—Ash-coloured shale		4	0
12.—Purple shale, striated with sandstone	3	5	3
Total thickness of Whitehaven sandstone at this point ...	28	3	6

The succession of beds, as near as can be ascertained, from the scanty outcroppings visible at Millyeat, is as follows :—

SECTION No. III.

1.—Grey sandstone.
2.—Liver-coloured shale.
3.—Grey sandstone.

The iron ore is in No. 2 of this section which doubtless is the same as beds 6, 7, and 8 of Section No. 1, and as beds 4 and 5 in Section No. 2, so that the Millyeat ore may be said to be about the middle of the Whitehaven Sandstone.

Breccia.—This lowest representative of the Permians in this district consists of fragments—some angular, others rounded—of all the rocks that have just been described. As shown in Plate XIX. and in Fig. 1, Plate XXI., it is unconformable to all the underlying formations. Its thickness seems to increase as the hills are approached. In Demesne Gill, on the road from Whitehaven to St. Bees, where it is overlaid by the Magnesian Limestone, it is only nine feet thick, whilst at Winder, with a denuded top, it has been proved to be 400 feet.

Hematite occurs in this formation in the form of rounded and angular fragments mixed up promiscuously with the other rocks. At times these hematite fragments are very numerous, and the "Miners" then call the formation "iron gravel," or "gravel ore." It has in one or two cases actually been worked for the iron it contains.

Magnesian Limestone and St. Bees Sandstone.—Neither of these formations, so far as can be seen, have any bearing on the subject, so that it will be unnecessary to say anything about them.

SUPERFICIAL DEPOSITS.—The chief point of interest presented by these beds at present is that they frequently rest directly upon the deposits of hematite. They also contain a number of fragments and boulders of hematite among the numerous rocks that compose their gravels and boulder clays, some of which fragments are polished and striated. Their thickness in some places exceeds 140 feet.

Before closing this introductory notice it would be profitable to glance for a few moments at some of the more salient points in the Geological history of the district. It will be seen, first of all, that, after the long period of deposition in which the vast mass of Silurians were thrown down, there succeeded a period of upheaval and severe denudation, in which those rocks were much dislocated and inclined, and a great part of them removed. Then came a submergence and the putting on of the Carboniferous rocks over the edge of the tilted and eroded Silurians. Layer after layer of these rocks were laid on until the huge pile included the Limestone, the Grits, and the productive Coal-measures. A second period of elevation and denudation then set in, and the newly-formed Carboniferous strata were fractured, uplifted, and inclined. At once meteoric and other kindred agencies commenced on them their work of destruction, which was continued without interruption until the quickly disappearing rocks were again submerged. The Whitehaven Sandstone was then spread out over their eroded edges and the long-continued Carboniferous era thus brought to a close. In a short time another upward movement was effected; this sandstone was eroded, and after a time sunk into the Permian Sea, where it was unconformably covered by the Breccia, the Magnesian Limestone, and the St. Bees Red Sandstone. Another rise then took place, the rocks reared their heads from out the "irony waters," and there they stood, thence onward to the "great ice age," subjecting themselves to a continuous attack of those meteoric forces by which they have been slowly moulded to their present form.

PART II.—POSITION, FORM, AND INNER NATURE OF THE DEPOSITS.

DEPOSITS IN THE ESKDALE GRANITE.—These are somewhat numerous, but not of any great importance commercially. The principal deposit hitherto worked is near the Boot in Eskdale. Another, but much smaller, deposit was worked near the "King of Prussia," in the same valley. They are all very much alike, both in form and inner nature, so that the one at Boot, which has been most worked, may be taken as typical. The form of this deposit is that of a vein. Its direction is nearly north and south, and it "hades" to the east at angles varying from 65 to 80 degrees

with the horizon. In that part of it which, so far as is known, is most fully developed, its existence is indicated on the surface by a small ravine known as Nab Ghyll, which runs down the southern side of the mountain that lies between Eskdale and the upper end of Miterdale. The ore is worked by levels driven into the hill at various heights, as shown in Fig. 2, Plate XXII., which is a longitudinal section of the vein. From this section it will be seen that the ore is not continuous throughout the vein, but that, as in most mineral veins, it occurs in "bunches" or "bellies." These bunches are usually thickest near their centre, whence they thin off, or, as the miners express it, "nip out," gradually towards the edges. Between the bunches there is invariably a "leader," but it contains very little ore, sometimes, in fact, none at all, being merely a strong joint. The length of vein that has been worked up to the present time is about 200 fathoms, and the depth to which the ore has been found to extend below the surface is about fifty fathoms. The greatest width of the vein has been about 20 feet, including 11 feet of "horse," or "rider." This was near the surface. Further down it is much narrower, and appears to die out altogether at a depth of fifty fathoms. It is, in fact, a "gash" vein. A section of it at the surface, as seen in No. 1 Quarry (Fig. 3, Plate XXII.), is shown in Fig. 3. It will be observed that at this point the vein consists of four distinct lots of ore, separated from one another by three ribs of "horse" or "rider." The "hade" of the ore, as well as its "direction" horizontally, agrees exactly with that of the large joints (*d*) intersecting the granite. These joints are very strong and persistent, and give the granite at a distance the appearance of bedded rocks standing on end. The beautiful ravine, on the opposite side of the valley, called Stanley Ghyll, seems to have been cut out along these points. Frequently, from the main line of ore, small strings of it are found branching out into the granite along some of the minor joints by which this, in common with other granites, is also intersected. If two of these strings cross one another a small branch is formed.

Near the surface, the "cheeks" of the vein are very much decomposed, being mostly so adjoining the ore, whence the granite becomes harder and harder, until at a distance of a foot or two from the vein it assumes its normal condition. The same thing occurs as the vein is penetrated, only the amount of decomposition and the distance to which it extends into the cheek becomes less and less in depth, until a few fathoms below the ore is reached, where the granite seems to be very little, if at all, altered. It is also observable that the cheeks are more decomposed where the vein contains ore than where it is barren.

Those parts of the veins marked *c* in Fig. 3 are not solid masses of hematite but a mixture of red earthy-looking ore, hard fibrous kidney of a purplish tint, black oxide of manganese, reddish clay, grains of quartz similar to those in the granite, and pieces of more or less decomposed granite. Generally these various materials are arranged in broken lines parallel to the sides of the lode, as shown at *c''* in Fig. 3. Some of the more earthy-looking ore contains pieces of decomposed felspar, and it is sometimes possible to trace this ore, on the one hand, into hard pure kidney, and on the other into granite but very little altered—that is to say, there seems to be, in such a case, a gradual transition from granite to pure hematite. Some pieces of ore have been obtained from this mine having the appearance of "ring ore." They are usually less than an inch in diameter, and in cross section present a number of concentric rings, somewhat like the annual layers of an exogenous tree. Down the centre there is frequently a hole as if the substance around which they seem to have been formed had disappeared.

Deposits in the Skiddaw Slate.—At one place only has hematite been worked successfully in these rocks—that is at Kelton Fell and Knockmurton, two adjoining properties on one of the hills near Ennerdale Lake, in the N.E. part of the district. The ore there occurs in the form of veins as at Eskdale, but in two sets, one running about 37 degrees N.W. and S.E., and the other about 15 degrees N.E. and S.W. Seven separate principal veins have been more or less worked, five of which have the former direction and two the latter. They all "hade" towards the east at angles varying from 45 degrees to 80 degrees with the horizon. The greatest length that has been worked on any of them is about 240 fathoms, and the greatest depth 56 fathoms.

The ore is not continuous but occurs in irregular detached masses or "bunches," as at Eskdale (Fig. 2, Plate XXII.) These masses are thickest near their centre, having been known at Kelton No. 1 Vein to be as much as 23 feet, but in this there was about nine or ten feet of "rider." Usually they vary from two to ten feet, and thin off gradually from the centre to their extremities. Exceptions to this are occasionally met with, and the ore terminates very abruptly, as shown in Fig. 1, Plate XXIII., which is a vertical section through the lower part of one of these bunches in No. 1 Vein, Knockmurton. Some of the bunches are over fifty fathoms in length. Between them the vein is nearly barren; sometimes, in fact, quite so, there being only a strong point or two to mark its existence.

At Eskdale it has been seen that the vein is widest at the surface, becoming gradually narrower as it goes further down. Here it is so, too, in

some cases, but in others the greatest width of the veins appears to be at some fathoms below the surface.

From what has been previously said respecting the joints traversing the Skiddaw slates, and more recently as to the bearing of these veins, it appears that the two are exactly parallel both in direction and "hade." In the mine this may be often very well observed directly, especially where there is a narrow string of ore occurring interruptedly, for it can then be seen most distinctly that the ore actually occurs in these joints, which by some means have been enlarged. This correspondence may also be seen in any of the small strings which branch out from the sides of the main veins. It was previously stated that one set of joints sometimes coincides with the dip and strike of the strata. When that is so, and ore occurs along the joints, the deposit has a bed-like form, as shown in Fig. 1, Plate XXIII., being in fact a "bedded vein."

At the surface the "cheeks" of the vein are very much altered from the normal condition of such rocks, being softer and more broken up; but, as they get deeper they become harder and less altered. They are, moreover, less changed in those parts of the vein which are barren than in the productive parts.

The ore is, as a rule, much less mixed with extraneous matter than that of the veins in the granite. Like them, however, everything, be it ore or not, is arranged in lines parallel to the "cheeks." Usually a layer of hard kidney ore is found running along both cheeks in concretions about an inch or two thick, the central part of the vein being filled with softer ore, as in Fig. 2, Plate XXIII. Along the cheeks of some of the narrower veins, and near the surface, are loughs filled with "combed" white quartz, and between these soft earthy ore has been found. Some of the ore in the centre of the veins is broken kidney, which is quite rotten, and lies in the most confused manner among ore of an earthy nature. Broken kidney ore is also met with embedded in brown spar, as shown in Fig. 3, Plate XXIII. It appears then to be in what was originally a "lough."

Most of the kidney ore next the "cheeks" has the convex side of the concretions turned towards the vein, but sometimes it is set in the opposite direction and faces the "cheek," seeming as if the different layers had been put on from the centre outwards. In some of the wider veins layers of hard massive ore occur. They are parallel to the "cheeks," and in some cases three or four feet wide, the remainder of the vein being soft ore, as above described. "Loughs" are frequently met with in the ore, as shown at *c*, Fig. 2. The sides of these loughs are composed of kidney ore, and they often contain a quantity of minute crystals of quartz, some of which are

coloured red by peroxide of iron. Here too, as at Eskdale, some of the ore assumes the ring form, and some of it is quite soft and micaceous.

One other feature of these veins remains to be noticed and that is the occurrence in them of ribs of "rider" and small pieces of slate. The "rider" or "riders" (for sometimes there is more than one) are of the country" rock, much decomposed, and have the same "hade" as the vein. The small pieces of slate lie scattered here and there through the ore. Some of them are very much decomposed, others are so deeply impregnated with peroxide of iron as to be almost indistinguishable from the more earthy ore in which they lie, whilst some appear to be very little altered. Fig. 4, Plate XXIII., shows the way in which the smallest of these fragments are sometimes embedded in the ore, giving it, at a distance, the appearance of a porphyritic rock.

The tender nature of the "cheeks" renders it somewhat difficult to keep the ore clean, otherwise it is of excellent quality, as shown by the following analysis:—

Peroxide of iron	89·21
Siliceous matter	7·07
Water and carbonic acid	2·53
Lime, alumina, etc.	1·19
	100·00
Iron	62·45

This was in all probability a picked specimen free from mechanical impurities. The following is more like the average composition:—

DRIED AT 212° FAH.

Ferric oxide	80·22
Manganous oxide...	·04
Alumina	·26
Lime	1·64
Magnesia	·03
Phosphoric acid	·03
Sulphur	traces.
*Insoluble siliceous matter	16·70
Carbonic acid and water	1·20
	100·12
Iron	56·15

The raw ore contains—

Moisture	3·77
Iron	54·03

*Consisting of—Silica	13·10
Alumina	3·60
	16·70

Deposits in the Coniston Limestone. — In this formation also hematite has been found, and at one place in such quantity as to induce persons to work it—that is at Water Blean, near Millom, in the southern part of the district. Much of the ore obtained from this place has been used as a pigment, owing to its high red colour, but a considerable quantity of it has also been converted into iron. The principal part of this paint ore was obtained from a cavity in the limestone immediately below the boulder drift. This is shown in Plate XXIV. That part of the cavity which, in Fig. 1, is bounded by a full line, was merely a dish-like hollow in the limestone, so that the ore was lying just under the boulder drift. The part shown in dotted lines had a cavernous form, and between the drift and the ore there was a roof of limestone. This will be further explained by reference to sections Figs. 2 and 3, which are sections along the lines A B and C D respectively. It will be noticed that some portions of the cavity have a N.W. and S.E. direction, whilst others have a N.E. and S.W. course. These two directions, it will be further noticed, correspond with the two sets of joints a'' and a''' by which the limestone is intersected. Their average bearing may be taken at 50 degrees N.W. and S.E., and 40 degrees N.E. and S.W. Fig. 4 is a section along E F.

Besides the ore obtained from the cavity shown in Plate XXIV., one or two short vein-like deposits have been worked which extend to a much greater depth. The greatest depth yet proved on any of them is 17 fathoms, at one part of which the ore has been worked from the surface to a depth of 13 fathoms without reaching the bottom. As in the veins in the granite and Skiddaw slate, the ore is not continuous, but occurs in short "bellies" somewhat like "pipes" or "chimneys." The greatest width yet met with has been about 14 feet. This was at the surface. Thirteen fathoms below that, the width was only six feet. Between the "bellies" of ore in the deposit that has been most worked, the only indication of a vein is a strongly-marked joint which forms a continuation of the lying "cheek" of the "bellies." The "nipping out" of the ore and the consequent formation of "bellies" results from a closing in of the hanging side—for it cannot be called a "cheek"—upon this joint which maintains an undeviating course. The direction of these vein-like deposits is the same as that of the joints, which bear 50 degrees N.W. and S.E. The "hade" is likewise the same in both, being to the N.E.

The ore is not much mixed with the "country" rock or any other foreign substance. That from the vein-like deposits, especially in the deeper parts and against the hanging side, is generally very hard and of a

bluish iron grey, often very peculiarly marked by dark glistening spots. The ore against the lying "cheek" and in the top parts generally of the vein-like deposits, as well as in the shallow deposit shown in Plate XXIV., is somewhat different, being softer and of a reddish colour. It is what is called the paint ore. The composition of the harder ore is as follows:—

Peroxide of iron	65·31
Protoxide „	7·60
Silica	7·96
Alumina	7·93
Lime	1·62
Moisture	2·28
Carbonic acid	7·30
	100·00
Iron	51·63

When the ore comes in contact with the limestone there is sometimes a well defined line of junction in the form of a joint (being in fact a selvage), on one side of which there is limestone, and on the other ore. This is so in the lying side of the vein-like deposit above described, and at *l* and *l''*, Figs. 2 and 3, Plate XXIV. In other cases the ore and stone seem "grown together," and are inseparable, there being a regular gradation from the one to the other.

In the softer ore some very curious structures occur which have been supposed by some to be fossil plants. Mr. E. W. Binney, in a paper read before the Manchester Literary and Philosophical Society in 1867, "On the Age of the Hematite Iron Deposits of Furness," speaks of having seen, in the possession of Miss Hodgson, of Ulverston, remains of Lepidodendra and Stigmaria, which were found in this deposit. Miss Hodgson, in a paper "On the Water Blean Iron Ore," published in the "Geological Magazine," March, 1870—prefacing her remarks by the statement that her information was received from the Manager of the Mines—says that "in the early part of the year 1866 a large tree trunk was met with standing erect," see *y*, Fig. 4. It was from 12 to 15 feet high, and from 20 to 24 inches in diameter at the base." As the miners came upon the tree at two levels (Miss Hodgson continues) "I was anxious to learn whether any bark-markings had presented themselves, but while it was admitted that, roughly, there might have been some resemblance to certain bark structures, yet it must mainly be described as having had 'a coarse sparry crust with vertical pipes' running through it." · · · "The above tree-like form was not the whole of the discovery; imbedded likewise in the ironstone, and occurring for the most part near the walls of the place, and low down,

were numerous twig-like remains. These are of a harder nature than the trunk mass—they are in better preservation—and in some specimens exhibit beautiful minute striation, with what seem to be little scars arranged in a uniform pattern."

The writer has in his possession a specimen of the tree trunk, and also a number of the twig-like remains, which he has examined very carefully. A section of the latter is given in Fig. 1., Plate XXV. They are, however, not all of the shape there shown, some of them having a crescent form in section, whilst others are nearly round. So far as the writer is able to judge, these so-called fossil plants are nothing more than concentric pipes of kidney ore, between the successive layers of which there is a thin ring formed by crystals of calcite; in fact, they seem to be but a particular case of "ring ore" structure, the so-called tree trunk being formed by a mass of these small structures in contact. The outermost ring is frequently marked by irregular flutings, as shown in Fig. 1, but these markings may also be found in other parts of the ore apart from the twig-like remains. The specimens in the possession of the writer do not, so far as he has seen, exhibit the "uniform pattern" alluded to by Miss Hodgson, and the only approach to it is the interior and exterior faces of the minute mamillations of the kidney rings. At first sight these certainly do present some resemblance to the markings of Lepidodendra and Stigmaria, but whether they are the characters upon which Mr. Binney based his generic determinations cannot be said.

Laminated barite, crystals of quartz, and "black muck," which consists of varying proportions of siliceous and aluminous materials, and of the oxide of iron and peroxide of manganese are sometimes associated with the ore of these deposits.

Deposits in the Carboniferous Limestone.—These are the most important deposits in the district. They are both large and numerous, are more varied in form, and present a number of interesting features which are not met with in any of the deposits previously described. As already stated, they occur in all the main beds of limestone that are yet known in the Lower Carboniferous Series of this district; but they are perhaps most numerous in the Langhorn and Clints beds, in one or other of which all the largest deposits in the district are found. Their form is variable, being sometimes *bed-like*, sometimes *vein-like*, at others filling *dish-like* hollows in the limestone immediately below the drift; whilst not unfrequently—but chiefly in the Clints Limestone—they are most irregularly shaped, and are at some depth in the limestone, by which and its associated rocks they are in most cases entirely surrounded.

THE BED-LIKE DEPOSITS occur mostly in the First Limestone, in fact the deposits in that bed assume this form exclusively; but the bed-like form is not confined to that horizon, for it is also met with in the Second, Fourth, Fifth, and Sixth beds of Limestone. As already stated, the First Limestone is overlaid by the Millstone Grit Series, the lowest bed of which is of a siliceous nature. Under the limestone is a thin silicious bed, usually called whirlstone; and then a bed of shale. In the Bigrigg locality these two beds are known as the "little whirlstone" and the "little sill" respectively. It is seldom that the ore occupies the whole thickness of the First Limestone, being mostly confined either to the top or bottom of it. At Frizington and Winder Gill it occurs in the top, as shown in Fig. 2, Plate XXV., which is a vertical section of part of the large deposit worked by the Parkside, Crossgill, and part of the High-house Mines. The "roof" of the ore is the bottom bed of the Grit Series, which has the same regular dip as the rest of the strata. The "sole," it might be expected, would be limestone, but curiously enough it is not, being nearly all silica, and called by the miners "whirlstone." A very remarkable feature of the limestone of this district, and one which seems scarcely ever to have been noticed, is that any bed of it at one place may be a pure limestone, whilst at another and not far distant place, the same bed may be the hardest whirlstone.* A recognition of this fact removes one of the greatest difficulties there is in the way of correlating the various sections that have been obtained in the different parts of the district. But to revert to Fig. 2, Plate XXV. Unlike the "roof," the "sole" is generally very uneven, being like a number of waves. These waves the miners call "rolls." Some of them are of great length, and they all run about west and south; the ends of them only are seen in Fig. 2, as the plane on which the section is taken cuts them at right angles. On the top of the "rolls" the ore is thinnest, being sometimes only a few inches; at others it is as much as twenty feet. In the hollows between the "rolls" the ore is of course thickest, being fully forty feet in some places. The sole has not this waved appearance everywhere, for it is occasionally found running for a considerable distance nearly parallel to the roof. Sometimes the ore is seen to run up into the grit roof in narrow strings, from an inch or two to a foot or more wide; and sometimes it extends from these strings along the bed joints, as shown at *e*, Fig. 2. All the strings have a north and south direction. The length of the deposit on a north and south line is

* This word is very loosely used in the district, being applied sometimes to hard sandstone, at others to grits, or, as above, to the siliceous portion of the limestones.

about 450 yards, and its breadth from east to west is about 370 yards. Its area is about thirty-four acres, so far as at present worked, being larger in superficial extent than any other deposit in the district. It has also yielded the largest quantity of ore. In plan it is as shown in Fig. 3, Plate XXV., its direction being nearly north and south. The tongues of ore extending from the north end of the main body have also this direction, which is the same as that of the "rolls" in the floor and the "strings" in the roof, the whole of them being parallel to the north and south joints intersecting the limestone. As shown in the section, the dip of the ore is to the west; on its eastern side it occurs just below the drift, but further westward, that is to the dip, the grits are put on over it; and by the time the western side of the deposit is reached it is overlaid by about sixty fathoms of these rocks.

At Bigrigg the ore is found in the First Limestone, at the bottom of the post, as shown in Fig. 1, Plate XXVI., which is a cross section of part of the large deposit worked by the Fletcher Pit, James Pit, Sir John Walsh Pit, Robin Beam Pit, etc. Here in many points a state of things is found exactly opposite to that which prevails at Frizington. There the roof is even and the floor uneven; here it is the floor that is even, whilst the roof is generally very irregular indeed. The "little whirlstone" forms the floor, and the roof consists chiefly of siliceous portions of the upper part of the First Limestone. Owing to the irregularity of the roof the thickness of the ore is very variable, being sometimes over thirty feet, and at others less than a foot. This great variation results mainly from the ore assuming at times certain vein-like extensions upwards, called by the miners "guts." These guts are shown at *f*, Fig. 1, Plate XXVI. They vary in width, from a few inches to five or six feet; and sometimes they open out under the basement bed of the grits and form a minor deposit along the top of the limestone. They are all nearly parallel, and run about north and south, as shown in Fig. 2, which is a plan of that part of the deposit worked by the Fletcher Pit and James Pit. The length of the whole deposit is about 550 yards, and its average breadth about 200 yards. As will be seen from the above plan, the ore does not lie in a compact body, as at Parkside, but is split up by elongated masses of limestone into parts, which bear nearly north and south. On the western side of the deposit these rock masses increase to such an extent, as compared with the ore, that the latter is only like a network of "guts" or veins, but their direction is parallel to that of the larger masses, both being in fact parallel to the north and south joints intersecting the limestone. The dip is to the

west, and, as at Parkside, the ore at its rise edge occurs immediately below the drift, but soon becomes covered, dipward, by grits and Permians, as shown in Fig. 1. At the James Pit on the west side of the deposit the thickness of these overlying rocks is about sixty-four fathoms.

Besides these deposits there are several others in the First Limestone, but they are all more or less similar to those described, so that it is not necessary to speak of them separately. In the Second Limestone the deposits have also a bed-like form. They chiefly differ from the deposits in the Top Limestone, in that they usually occupy the full depth of the bed, have a regular "roof" and "sole," and are consequently of more uniform thickness. The writer is not aware that this form of deposit has been met with in the Clints Limestone, but a good example of it in the Fourth Limestone may be seen in the No. 7 Pit of the Salter and Eskett Park Company. A section of this deposit is given in Plate XXVII.

From the high angle at which it dips it is generally spoken of as a vein, the miners working it using the terms "hanging cheek" and "lying cheek" for what are in reality the "roof" and the "sole" respectively. A little to the S.E. of the section the ore is cut off by a large west and south upthrow fault, which brings the Skiddaw slate to the surface. The throw of this fault at the Agnes Pit, a little to the north of the section, is about 190 fathoms, the Skiddaw slate and St. Bees Sandstone being in contact. Where the ore (shown in Plate XXVII.) abuts against this fault it is very thin, but it becomes thicker to the dip, as shown in the section. The "roof" is formed by a bed of shale generally, and so is a great part of the "sole;" but sometimes irregular masses of siliceous stone, *g*, are found intervening, so that for a time the "roof" or "sole," or both, may be stone. The length and breadth of the deposit have not yet been proved, as the limit of the ore has only been reached on two adjacent sides.

Bed-like deposits also occur in the Fifth and Bottom Limestones, as shown in Fig. 1, Plate XXVIII., A and B, respectively. They present no peculiar features, and therefore need not be separately described. It may, however, be observed that their bearing agrees with that of the main joints in the limestone, being nearly north and south.

Vein-like Deposits.—Perhaps the best example in the district is that which is worked by the Salter Hall Mines, and the Eskett Mines of Mr. John Postlethwaite. It is on the line of a large north and south fault, having an upthrow to the west at Mr. Postlethwaite's mine of about 120 fathoms. As worked by the Salter Hall Mines, the deposit is in the Clints Limestone, and at its south end very shallow, being overlaid only by the drift; but, having the same dip as the strata, that is to the N.W.,

it gets deeper as it goes towards the Eskett Mines; at the same time it rises through the Second Limestone into the First, being in fact partly in the whole three. It is there that it becomes the most vein-like, its section being as shown in Fig. 1, Plate XXVIII. The ore, it will be noticed, is very narrow nearly to the bottom of the section; it then widens considerably, and the "hanging cheek" changes its character. Above this point it is very siliceous, but here the rocks contain a large proportion of lime. On the upside of the fault there is Skiddaw slate for about one-third of the depth of the section, the remainder being "whirlstone," limestone, and shale, intercalated with which are two bed-like extensions of the vein ore, called by the miners "flats" or "flat ore," the uppermost being in the Fifth, and the lower in the Bottom Limestone. There is thus the fact of a deposit of ore—for really the whole of the ore, both bed-like and vein-like, may be looked upon as one deposit only—being partly in the First, partly in the Second, and partly in the Third, Fifth, and Sixth Limestones. In the Salter Hall Mines the ore frequently formed "flats" on the down-side of the fault as well as on the up-side.

Another large vein-like deposit is found by the side of the north and south fault, running through by Agnes Pit and Yeathouse Pits. Its character throughout is very similar to that just described; but at Agnes Pit the "flats" occur only in the hanging or down-side, the up-side of the fault consisting entirely of Skiddaw slate. On the contrary, the "flats" at Yeathouse Mines are wholly in the up-side, the "hanging cheek" being Breccia and St. Bees Sandstone.

At Birks there is another vein-like deposit, which is also on the line of a north and south fault. There, too, as at Yeathouse, the "flats" are in the up-side, the down-side being St. Bees Sandstone and Breccia.

A feature of these vein-like deposits worthy of mention is that they all "hade" towards the east, like the veins in the granite and Skiddaw slate, the amount of "hade" being usually as in Fig. 1, Plate XXVIII.

Dish-like Deposits are not numerous, nor, with one exception, are they important. The exception is the new deposit at Hodbarrow, a section of which is given in Fig. 2, Plate XXVIII. It occurs in the Thick Limestone of Furness. Its extent has not been fully ascertained yet, but its length, so far as is known, is about 800 yards, and its breadth about 190 yards; its greatest thickness is about 90 feet, and the average perhaps 55 feet. The deposit contains very little stone or other foreign matter, so that it may be looked upon as a solid mass of ore. It is one of the largest deposits in the whole district, and the only one of its kind of any importance, although in Furness they are very common; in fact, in

that district, most of the large deposits have a dish-like form. As shown in Fig. 2, it is overlaid only by sand, gravel, and clay of the drift period, whilst below and around it is one mass of limestone. Its direction is nearly north and south and corresponds exactly with that of the main joints in the limestone.

Irregularly Shaped Deposits.—The best example is probably that worked by Lord Leconfield's Wyndham Pit, and No. 7 Pit at Bigrigg. That deposit occurs in the Clints Limestone on the south side of an east and west fault, which throws up to the south about 19 fathoms, and cuts off the grits of Fletcher Pit and James Pit, at the same time bringing up the "little whirlstone" to the surface and exposing it to view in the bottom of Langhorn Quarry. A section of the deposit is shown in Fig. 1, Plate XXIX. On the north side of the fault are bed-like deposits in the First and Second Limestone, which were worked by Lord Leconfield's No. 5 and 6 Pits. The deposit under consideration is on the opposite side of the fault. When viewed in section, as above, its outline is most irregular; and so is its horizontal profile, tongues of limestone of various lengths and breadths running into it in a north and south direction, and splitting it up in the most fantastic manner. Its greatest length is about 340 yards, its greatest breadth 208 yards, and its greatest thickness 200 feet. Owing, however, to the splitting up of the deposit by masses of limestone, its average dimensions probably do not equal half its greatest dimensions. The lower part of the deposit is somewhat bed-like, having the same dip and strike as the strata; and the ore connecting this with the main mass above has a pipe-like form, its area in horizontal section being very small. The general direction of the deposit is north and south, and so is that of the integral masses of ore into which the deposit is divided by the protruding tongues of limestone. The "roof" of part of the deposit is formed by a bed of shale; everywhere else it is enclosed by limestone, or its siliceous concomitant, "whirlstone."

Another very large deposit of the same kind, and in the same limestone, is being worked at Montreal Mines, by Mr. Stirling. It occurs on the south side of a large east and west vein, which has a throw at that point of about 240 fathoms. Its length from north to south is about 220 yards, its breadth about 180 yards, and its average thickness about 45 feet. Other similar deposits occur in the same limestone in various parts of the district, but there is nothing about them which is peculiar, so far as regards their form; so that they demand no special notice.

The particular *forms* of the deposits having been described, it is now proposed to glance at their more *general features*.

In the case of some of the deposits already spoken of it was stated that they were split up by tongues of limestone or "whirlstone" in such a way that the bearing of the different parts of the deposit corresponded very nearly with the magnetic meridian. This may be said to be the case generally, unless the deposit occurs alongside an east and west fault. Then it sometimes happens that the longer axis has an east and west direction. For instance, alongside the coal-measure fault which runs in an east and west direction through the Montreal Mines, there is a deposit of ore which extends from No. 2 Pit Montreal to No. 2 Pit Cross-field, a distance of about 320 yards, whilst its greatest extension southwards from the fault is only 150 yards. It is, however, only in a case of this sort that a deposit is longer in an east and west direction than it is from north to south; and not always then, for the Wyndham Pit deposit at Bigrigg is twice as long in a north and south direction as it is from east to west; yet it occurs by the side of an east and west fault.

Another feature of these deposits as they occur in the northern part of the district is that they usually lie by the side of a fault, a fact the importance of which will be rendered more clear by an enumeration of the principal deposits so occurring. As shown on Plate XIX., every fault of any importance runs either in a north and south direction, or nearly at right angles to it; so that deposits in this connection may be divided into two sets—those by the side of north and south faults, and those by the side of faults having an east and west direction.

Deposits alongside North and South Faults.—The deposit worked by the Salter Hall Mines, the adjoining part of the Salter and Eskett Park Company's mines, Mr. John Postlethwaite's mines, and the new mines of the Winder Iron Ore Company is partly on the up and partly on the down-side of a large fault which runs through by Winder Station.

Coming further west there is another fault at Yeathouse, by the side of which are deposits that have been worked by the Eskett Iron Ore Company's mines, part of the Salter and Eskett Park Company's mines, part of the mines of the Winder Iron Ore Company, the Yeathouse Mines, and Messrs. Lindow's Dyke Nook Mines.

The next fault of any importance is at Birks, alongside which lies the deposit worked by Mr. Joseph Fearon.

Coming down to Cleator, there is a fault running through the Crossfield Company's No. 10 Pit, and another by the Cleator Iron Ore Company's old opencast, the opencast and No. 7 and No. 8 Pits of the Crossfield Iron Ore Company, and Mr. Stirling's No. 5 and No. 7 Pits.

At Bigrigg there is another fault, by the side of which is the Ehen Company's pit, the old pits worked by Lord Leconfield on Bigrigg and the Meadow, and the James pit of Messrs. Lindow.

Deposits alongside East and West Faults.—By the side of a fault with this direction are Lord Leconfield's Bigrigg pits, and some of the Woodend pits.

Another fault on the north of Sir John Walsh Pit passes by one or two old pits belonging to the Cleator Iron Ore Company. The fault in Todholes Quarry is probably the same.

Along the fault already mentioned as passing through Montreal mines are the Moor Row Company's pits; Mr. Stirling's pits numbered 1, 2, 3, 4, 6, 11, and 12; the Crossfield Company's No. 2 Pit; and Lord Leconfield's James Pit.

At Frizington a fault runs through Messrs. Fletcher and Hodgett's pits, numbered 1, 2, and 5, and between the Goose Green and Scalelands pits.

Lastly, there is a fault with this direction running through the Mowbray Company's No. 2 Pit shaft. Some of the pits along these lines of faulting are perhaps omitted, but the principal are included, from which it will be seen that all the most important deposits in the district are by the side of faults. It may also be observed that the north and south faults "hade" to the east, whilst those having a direction nearly at right angles to them "hade" to the north.

Another feature of importance in these deposits is that they all, at some part or other, rise out to the denuded surface of the tilted Carboniferous rocks and are there covered only by Permian Breccia or drift.

The ore is chiefly of the hard massive kind, although in some places it is much harder than in others. In colour it varies from a brownish red to a bluish iron grey. Its composition is shown by the following analyses:—

No. 1.

Peroxide of iron	98·26
Silica	1·59
Phosphate of iron	·30
Lime and magnesia	traces.
	100·15
Iron	68·78

This was a picked specimen from the Parkside Mines, the average composition is, however, more like that shown in No. 2, which is an average of twenty-four analyses of ore from the Salter Hall deposit.

	No. 2.
Peroxide of iron	86·37
Alumina	1·21
Silica	9·56
Lime, water, etc.	2·57
	99·71
Iron	60·45

The difference between No. 1 and No. 2 analyses conveys some idea of the great variation there is in the quality of the ore. It is, however, still more apparent from No. 3 and No. 4 analyses of ore from the Yeathouse Mines :—

	No. 3.	No. 4.
Peroxide of iron	86·33	63·04
Silica	9·73	37·24
Alumina	trace.	——
Water and loss	3·94	——
Carbonic acid	——	·90
Lime and magnesia	——	trace.
	100·00	101·18
Iron	...60·43	44·12

In the separate analyses, of which No. 2 is an average, the lowest percentage of silica was 3·19, and the highest 24·78. In some deposits the ore contains a small percentage of protoxide of manganese, and traces of sulphur and phosphoric acid.

Here and there in the ore are small cavernous spaces called "loughs," which vary in shape from lenticular to spheroidal, and in size from a few inches to three or four feet across. Invariably the ore forming the walls of these "loughs" has the kidney structure as shown in Fig. 2, Plate XXIX. It occurs in concretions round the "lough" to a depth of several inches, becoming less and less distinct outwards from the "lough," and finally dies away into the massive ore around it. Some of these "loughs" are filled with brown spar, as shown in Fig. 3, Plate XXIX. The ore sometimes appears to be interlayered with the brown spar, as shown in Fig. 2, and at other times broken pieces of kidney are found lying pell-mell in the spar, as shown in Fig. 3, Plate XXIII.

When the ore is in contact with either shale or sandstone, there is a distinct line of demarcation between them, but this is rarely so when it is in contact with limestone or "whirlstone." The junction then is usually as shown in Fig. 1, Plate XXX., the ore and stone being, as the miners express it, "grown together." The passage from one to the other is by regular gradations. Very frequently the ore for a few inches next the stone has a laminated appearance, that structure being most distinct

near to the stone, and becoming less and less so as it recedes from it. Sometimes between the ore and stone there is a thin parting of clay, but it seldom if ever exceeds half-an-inch. In some cases the stone adjoining the ore, and for two or three feet away from it, is of quite a porous nature, being at one time black and cindery-looking, at another yellow and ochreous, or gossany, or again, it may be a dullish brown.

A most remarkable feature of these deposits when in the Third, Fourth, Fifth, or Sixth Limestones, is the occurrence in them of partings and nests of shale. Fig. 2, Plate XXX., shows several of these partings; it is a section exposed in the No. 5 Pit of the Salter and Eskett Park Company. The beds between which the partings occur are partly siliceous stone, and partly hard jointy hematite, and they have the same dip both in direction and amount as the rocks surrounding the deposit. A similar section seen in Salter Hall No. 3 Pit is given in Fig. 3, Plate XXX. Here, again, the beds of ore and the shale partings have the same dip as the surrounding strata, with which in fact the partings are actually interbedded. The pieces of "whirlstone" *b* and *b''*, which are separated by the partings *c'* were proved at several points to be connected with, in fact to form part of, the surrounding rocks, so that the partings *c* and *c'* are interbedded with the limestone as well as with the ore. The same thing may be also seen in Fig. 1, Plate XXXI., which is a cross-section of the Crossfield Company's "opencut." Here the shale bed *f* was seen lying between the ore *d d'*, and also continuing on between the beds of limestone *c* and *c'* for as far, at least, as shown in the section. Fig. 2, Plate XXXI., is a section seen in the Eskett Iron Ore Company's No. 4 Pit. Nests of shale, as shown, were surrounded entirely by hematite. The horizontal section of these nests were roughly circular, and the laminations of the shale were parallel to the "roof" *b*, which is the same bed as that overlying the ore shown in Plate XXVII. A similar nest of shale is shown in Fig. 3, Plate XXXI., which is a section seen in Lord Leconfield's Wyndham Pit, at Bigrigg. The laminations of the shale are in this case also parallel to the bedding of the surrounding rocks.

Another fact of frequent occurrence, which it is desirable to mention, is the shaly nature of the "roof." In Plate XXVII., Fig. 1, Plate XXIX., Figs. 1 and 2, Plate XXXI., there are deposits with shale "roofs;" and in Fig. 1, Plate XXIX., it may be seen that the shale beds *c* and *c'*, forming the "roof" of *e''* and *e'''* repectively are interbedded with the surrounding rocks. This fact is also seen in Fig. 1, Plate XXXII., which is a section of the deposits worked by the Scalelands Company. In this section there are shale beds *c'* and *c''* interbedded with the limestone, forming also the "roof" of the deposits *d'* and *d''* respectively. A very

curious section of a deposit with a shale "roof" is given in Fig. 2, Plate XXXII.; it was seen in No. 1 Pit, belonging to the Salter Hall Company. Overlying the ore there was a thin bed of shale, which suddenly thickened as shown at *c*. At the same time the ore below it changed entirely in quality, becoming very much poorer; in fact, the change was from good hematite to a substance little better than irony stone.

A fact which the writer has very often noticed in connection with the shale partings, as well as with the "roof" and "sole," when either or both of them is shale, is that the ore next the shale, if that be not black and slaty, is very much softer than it is a foot or so away from it, the softness increasing as the shale is approached.

In some of these deposits the ore has quite a bedded appearance. This feature is very well displayed in Todholes Quarry, below the shale beds which ran through the ore, as mentioned in Part I. of the Iron Ores of Great Britain. It may also be seen in the Cleator Iron Ore Company's new "opencut," of which Fig. 3, Plate XXXII., is a cross section. At a distance the ore has all the appearance of red stained limestone, such as may be seen near Park Mines in Furness. The dip of those beds, as shown in Fig. 3, corresponds exactly, both in direction and amount, with that of the adjoining limestone, on the same side of the fault. Sometimes where the ore is bedded in this way the alternate layers are hard and soft.

Another fact of frequent occurrence, which may also be seen at the Cleator Iron Ore Company's "opencut," is the existence of joints in the ore somewhat similar to the two sets of joints (beside the bed joints) by which all rocks are more or less intersected. One set, running nearly east and west, is shown in the section by short lines at right angles, or nearly so, to the bed joints. The other set runs nearly north and south, that is parallel to the plane of the section. They are not strong, persistent joints such as are found in the limestone, or even in the slate, but are quite short and interrupted, as represented in Fig. 3. So far as the writer's experience goes, they only occur in the hardest ore; and those having an east and west direction are more numerous and stronger than those running at right angles to them.

Fossils are sometimes met with in the ore, but they are very rare and restricted in variety. All those found by the writer are species of coral, and he is not aware that the remains of any other organic form have been found in this district. It has been several times asserted that certain species of Carboniferous plants had been found, but upon close inquiry it turned out that there was not sufficient evidence to show

exactly where they came from. Probably it was from the grit "roof" of the deposit in which they were said to be found, as the deposit in which these plants were alleged to be found, had a grit "roof."

Associated with the ore of these deposits are frequently found crystals of calcite, crystalised and granular dolomite, and crystals of quartz, more rarely barite, either laminated or in tabular crystals; also arragonite and pyrite. Once in Fletcher Pit, the writer met with flourite, and Mr. James Davidson states that he has found it in Lord Leconfield's mines at Bigrigg. These mines have also yielded a quantity of hausmannite. It occurs in "loughs" in the hematite, as shown in Fig. 1, Plate XXXIII. Gothite has also been found in them as shown in the above figure. In Birks Mines pyrolusite has been found; in the Eskett Iron Ore Company's mines manganite; and in Salter Hall Mines crystalised siderite and xanthosiderite. This latter mineral occurs along joints in the hematite, and has usually been looked upon by those who have seen it in the district as a fossil organic form.

Deposits in the Upper Coal-Measures. — The only deposit of hematite, in these rocks, that has been worked is that which occurs at Millyeat, near Frizington, in the northern part of the district. It is now sometime since it was worked, and no record appears to have been kept of what was done, so that there is not very much known about it. The ore occurs in the form of a bed, as shown in Fig. 3, Plate XXXIII., which gives a plan and section of it.

Both above and below the ore there is a thick bed of liver-coloured shale (6 and 8 of No. 1 section in the introductory description of the Coal-measures), as seen in the above plan and section, but which is more distinctly shown in Fig. 2, which is a section of the bed as seen by the writer in the bottom of the stream that runs down by the mill.

Here the ore is split up into three minor beds by intermediate layers of soft shale, but on the S.E. side of the valley, where it was worked, it was still more divided, as shown by the following section :—

	Ft.	In.		In.
1.—Ore	1	0	...	—
2.—Clay		—	...	1
3.—Ore		2	...	—
4.—Clay		—	...	½
5.—Ore		1½	...	—
6.—Clay		—	...	¾
7.—Ore		¾	...	—
8.—Clay		—	...	4
9.—Ore		2½	...	—
	1	6¼	+	6¼ = 2′ 0½″

The quality of the ore is very variable, but the best of it is about as pure as any that has been found in the district, as the following analysis will show:—

	No. 1.	No. 2.
Peroxide of iron	97·85	96·40
Phosphate of iron	·71	·80
Silica	1·44	1·20
Lime	trace	1·60
Magnesia	...	
	100·00	100·00
Iron	68·5	67·48

The appearance of this ore, both as regards colour and texture, is very much like the finest tool steel, but the poorer ore is quite earthy looking and of a bright red colour. It contains a large proportion of lime. In some cases thin irregular layers of limestone are actually seen in it, and in some places it is very much intersected by joints.

PART III.—AGE OF THE DEPOSITS.

On this point more has been written than on any other connected with the subject. So far as the writer has been able to gather from what has been said there seems to be a general agreement that the ore is older than a great part of the Permians. This, in fact, is proved by the existence of hematite fragments in the Lower Permian Breccia. But how much older it is than this breccia is a point which has not yet been satisfactorily answered.

Professor Harkness and Sir Roderick Murchison, in a paper on the "Permian Rocks of the North-west of England," read Feb. 3rd, 1864, before the Geological Society, say—"The mode in which that valuable ore of iron, hematite, is found deposited in pre-existing cavities of the carboniferous formation, and sealed up by "crab rock," is a matter of great geological interest. Joints, fissures, and caverns were doubtless formed in the older rocks antecedent to the deposition of the Permian Strata, and in these the ore of iron, so widely diffused throughout the Permian Rocks, have in this portion of the north-western region assumed the characters of hematite. This circumstance justifies the inference that these hematite ores are the result of an agency which ushered in the Permian epoch. The earlier Permian Rocks of both England and Scotland are strongly impregnated with iron, their composition consisting principally of silica and an oxide of this metal. This latter substance originated from the same source which, during the commencement of the deposition of the Penrith Sandstones, filled up the fissures in the Carboniferous Limestone.

This conclusion is applicable not only to the Ulverston district but also to that of Cleator, south-east of Whitehaven, where valuable deposits of hematite are also obtained from the cavities and fissures in the Carboniferous Limestone which, at one time, was here covered over by an extension of those Permian breccias and sandstones now forming an escarpment a short distance west from Cleator Moor."

In a paper of the author's on the "Hematite Deposits of Whitehaven and Furness," read before the Manchester Geological Society, January, 1875, he ventured to dispute the conclusion of these authorities, that the "Crab-rock" of Furness was a Permian breccia, saying that "having carefully surveyed the whole district, he believed this 'Crab-rock' belongs to the drift period and not to the Permian system at all." This conclusion is supported by the map of that district, recently published by the Geological Survey. On that map no notice is taken of the "Crab-rock," but surely there would have been had the surveyors considered it to belong either to the Permians or to any other group of rocks below the drift. This "Crab-rock," therefore, affords no evidence whatever of the Permian age of the hematite, for that ore might, for anything this breccia proves to the contrary, have been deposited during the Trias, or even during the Jurassic or Tertiary period.

Mr. E. W. Binney, in a paper entitled "A glance at the Geology of Low Furness, Lancashire," read before the Manchester Literary and Philosophical Society, Dec. 28th, 1847, says—"The beds of iron appear to have been formed after the Carboniferous Limestone, and before the deposition of the Upper New Red Sandstone." The same writer, before the same Society, Nov. 15th, 1853, in a paper "On the Origin of Ironstones, and more particularly the newly-discovered Red Stone at Ipstones, near Cheadle, Staffordshire, with some account of the Ironstones of South Lancashire," says—"The position of the bed of hematite at Ipstones is between the upper part of the rough rock and the Woodhead Hill stone, somewhere near about the position of the nine-inch seam of coal in the author's section of the Lower Coal-field of Lancashire. In other districts where this little seam is found (and it is more constant in its thickness over a great distance than most other coals) some large deposits of carbonate of iron are met with in the shales above it; so iron then appeared generally purest in the waters of the carboniferous sea, and the cause of the deposit at Ipstones being preserved from being converted into a protoxide, most probably arose from there being a less quantity of vegetable matter in the waters thereabouts than had been generally the case during the deposition of the carboniferous strata." Again in a paper, "On the Age of Hematite

Iron Deposits of Furness," read before the above-named Society, Dec. 10, 1867, Mr. Binney says—"When his papers (the two quoted above) were written, conclusive evidence could only be given of the age of the hematite iron of Ipstones, in Staffordshire, which was clearly interstratified in the Lower Coal-measures between the Rough Rock or Upper Millstone Grit of Professor Phillips and the Geological Survey and the Gannister coal. Some years since Mr. Bolton, of Swarthmoor, near Ulverston, showed him, amongst other fossils, a beautiful specimen of *Sigillaria Vascularis*, exhibiting both its external characters and its internal structure, quite as perfect in every respect as the specimens found in the Gannister or hard coal at Halifax or the Bullion seam of Burnley, all converted into hematite iron. At this time no doubt existed in his mind of its having come from one of the Furness Iron Mines, but Mr. Bolton could give him no proof of the exact locality where it was found." Further on Mr. Binney writes (when referring to some specimens belonging to Miss E. Hodgson, of Ulverston)—"They do not exhibit their external characters so well as Mr. Swainson's (Mr. Bolton's) specimens do, but one is a *Stigmaria*, the root of *Sigillaria*, and another *Lepidodendron*, two common coal plants which indicate the carboniferous age of the deposits in which they were found as clearly as any fossil organic remains can do. There is no doubt about Miss Hodgson's specimens. They came from the Water Blean Mines, and plenty more may be obtained from the same place. They are all converted into good hematite iron, that substance having metallized them in a similar way, as we find plants in the Coal-measures converted into the carbonate of the protoxide of iron or carbonate of lime." And again—"The discovery of common coal plants not only embedded in but actually formed of hematite iron surely indicates the Carboniferous age of the deposits in which they are now found as clearly as it well can be, for the plants must have been floated in with the water which brought the iron, or else they must have fallen into the cavities when such were open at the top and the iron was in a soft state. Of course the occurrence of such plants as *Sigillaria*, *Lepidodendron*, and *Calamites*, occurring as they do, in beds from the lowest to the highest Carboniferous Strata, would give little evidence of any particular part of that epoch, but the *Sigillaria Vascularis*, so far as yet known, is confined to the Lower Coal-field, not far in geological position from the Ipstones hematite previously alluded to and the valuable clay-band ironstones now wrought at Hazlehead, west of Penistone. The deposits of hematite in Furness and Cumberland, found in hollows of the Carboniferous Limestone, and covered up by till or 'pinel,' as it is locally termed, or more rarely by Permian breccia, are so much alike in all their characters that if the origin

and age of one of them are clearly proved, those of the rest must follow almost as a necessary consequence."

The fact of hematite being interstratified with the Lower Coal-measures at Ipstone proves to Mr. Binney that that ore at any rate is of Lower Coal-measure age. The Furness deposits and those of this district he supposes to be of the same age from the fact of a *Sigillaria Vascularis*, converted into hematite, having, presumably, been found in one of the Furness deposits. But it has been seen that at Millyeat a bed of hematite is interstratified with the Upper Coal-measures. Now that cannot possibly be of Lower Coal-measure age, so that unless there have been two or more periods of hematite deposition in this district the other deposits are not of that age either. In tracing the physical history of the district it is soon perceived that from the commencement of the Carboniferous era to near its close there was no perceptible breach of continuity in the process of rock formation, but that from the bottom bed of Limestone to the top of the productive Coal-measures, layer after layer was laid on in uninterrupted conformity. This is proved by the absence of overlapping and the comparative regularity that prevails in the thickness of the strata formed, during that time, over the northern part of the district. The tilting and accompanying faulting of those rocks could not, therefore, take place before the period of upheaval and denudation which is marked by the physical break that occurs between the Lower and Upper Coal-measures. This being so, it follows, if the ore in the Carboniferous Limestone is of the Lower Coal-measure age, as Mr. Binney says, that these deposits must have been intersected by the faults alongside which they lie; but is this so? In Fig. 1, Plate XXIX., there are what may be looked upon as three distinct deposits of ore—e', e'' and e'''—the two first being on the north side of the fault, and the last on the south. Had these deposits been intersected by the fault—that is to say had the ore been there before the fault was formed, part of e' and e'' would have been found on the south side of that fault and part of e''' on the north side of it. But this is not so, and therefore it follows that these deposits, at any rate, could not possibly be of the Lower Coal-measure age, in fact they could not have been formed before the submergence which preceded the deposition of the Whitehaven Sandstone, so that they are probably of the same age as the Millyeat ore. It will thus be seen that both the Upper and Lower Carboniferous deposits are younger than they are supposed to be by Mr. Binney, for what has been proved of the deposits shown in Plate XXIX., Fig. 1, is equally true of all the others in the same rocks, although it cannot be directly demonstrated for the simple reason that in every other case, so far as the writer is aware, the throw of

the fault is so large that, either the limestone in which the deposit occurs on one side is thrown off on the other, or that the pits working the deposit on one side are not sufficiently deep to enable the corresponding horizon on the other to be reached, or if deep enough, are not on the right side of the fault.

A glance at Plate XIX. will show that those east and west faults which are up to the south are entirely pre-permian, their last movement having taken place since the deposition of the Whitehaven Sandstone. The extent of that movement has not yet been ascertained, but it is certainly over thirty fathoms in some cases, for the great Coal-measure fault has thrown the Whitehaven Sandstone out altogether on the south. The principal north and south faults are also of pre-permian origin, but they have had a movement since the deposition of the St. Bees Sandstone. In some cases this movement has amounted to sixty fathoms. Now, since the ore was certainly deposited before this movement took place, it will be seen that alongside a north and south fault a deposit of hematite in the same bed of limestone may be very much higher on one side of that fault than it is on the other and yet not be older than the fault, but simply older than the last movement of it. These remarks are made by way of reply to those who maintain that, because they have seen a deposit of ore thrown by a north and south fault, all faults must necessarily be younger than the ore. To those who hold this view it seems that the large masses of ore which lie by the great Coal-measure fault at Montreal Mines are but parts of still larger deposits which have been intersected and dislocated by the fault, the remainder of the ore being at a depth of nearly 300 fathoms and under the Cleator Moor Coal-field. The fallacy of such an assumption as this—for it is nothing more—the author would submit, must be apparent to any one who has considered the above observations. So far from this fault having had a movement of about 240 fathoms (its full throw), since the deposition of the ore, it seems extremely probable that it has never moved at all. In saying this the author is not unmindful of what he has previously said—that the ore in the Carboniferous Limestone and the Millyeat ore are probably of the same age. The point is pressed also with due regard to the statement, just now put forward, that some of the east and west faults have had a movement of unascertained extent, since the formation of the Whitehaven Sandstone, in which, like a bed, the Millyeat ore occurs. The reconciliation of these apparently contradictory statements will be found in the explanation which will be given further on of the origin of the deposits.

Returning to the starting point of the above digression, the inference still remains that the ore in the Carboniferous rocks could not have been

deposited before the submergence which resulted in the formation of the Whitehaven Sandstone. The deposits in the granite, the Skiddaw slate, and the Coniston limestone, are doubtless of the same age, although at present there seems to be no means of proving it, but it does not appear at all likely that there was more than one period of hematite deposition. The way in which the veins in the granite and Skiddaw slate occur in the sides of hills, dying out at a comparatively uniform depth below the surface of those hills, notwithstanding that that surface varies very considerably in altitude, as shown in Fig. 2, Plate XXII., suggests, if it does not prove, that the ore in these older rocks was not deposited until after the hills had assumed somewhat of their present contour. Altogether it may safely be considered that the hematite of West Cumberland is older than the Lower Permian breccia, but younger than the bulk of the Coal-measures. This conclusion is equally applicable to the Furness ore, as well as to that in the Carboniferous Limestone of Derbyshire, near Newhaven House, and that in the Lower Coal-measures of Staffordshire. The time during which it is possible for the ore to have been deposited is rendered by the above limitation, very small, geologically, but when the origin of the deposits is considered, there will probably be no difficulty in fixing their age.

IV.—ORIGIN OF THE DEPOSITS.

Various attempts have been made to answer this question, but none of them are at all satisfactory. Mr. Binney, in his paper on the Geology of Low Furness, already quoted, says—"The quantity (of iron) in the Iron Mines of Low Furness is such as to indicate a proximity to the source whence it originated. It appears to have been thrown up by volcanic action and then carried by some means into the valleys and fissures where it is now found. But whether the iron was injected into the places where it is now met with through the fissures immediately below, or was first mingled with the waters of the sea when they flowed through the fissures and caverns of the limestone and gradually filled them up with the metallic matter held partly in solution, as Professor Sedgwick thinks, it is difficult to determine." Again, in his paper on the "Origin of Ironstones," Mr. Binney says—"After examining the beds of hematite found in the Carboniferous strata in regular beds, as in the vicinity of Whitehaven and those at Ipstones, no one can doubt that they had their origin in volcanic vents and flowed into the waters of the sea, where they were deposited, layer by layer, with the argillaceous and siliceous impurities found associated with them, like any other substance thrown down from suspension. This is evident from the beautifully laminated structure of the Ipstones

bed." In the discussion which took place in Manchester, after the publication of the author's paper on the Hematite Deposits of Whitehaven and Furness, Mr. William Brockbank is reported in Part 9, Vol. XIII. of the Manchester Geological Society's Transactions, to have said—"In the porphyry of Bowfell there are large veins of true kidney hematite ore, and especially in the hollow or cleft between its two summits. The pike of Bliscoe, in Langdale, is deeply veined with hematite and the red tarn behind its summit derives its name from the hematites which form its shores. Indeed so rich are the veins of true hematite in the older rocks at the head of Langdale that it has been in prospect to carry a railway up to work them.

"There are true hematites near the summits of Scawfell. The screes at Wastwater are veined with them. Red pike or Ennerdale gets its colour and name from hematite ore, and in this locality it was smelted by the Romans. All these are in the syenite, porphyry, and other oldest igneous rocks. There are very rich mines now worked in clay slate at the foot of Grasmere, and there is a railway making up the Ravenglass valley to convey the ore from mines which occur in veins in the granite and other older rocks. At Lindal, in Cartmel, a vein of hematite can be seen between the clay slate and limestone, and all round Arnside Knott are true veins of hematite much altered by heat. These, then, are instances of the occurrence of hematite ores directly from their present source, and in my opinion they prove the origin of hematite ore to be igneous." Further on Mr. Brockbank is reported to have said—"Now, Professor Phillips describes the great igneous, granite, and syenitic masses about Scawfell and Bowfell as having been in fusion since the deposition of the clay slates, because the latter are everywhere found to be indurated and metamorphosed by their action. It is these very igneous rocks which now bear the hematite veins above described, and we thus have a direct clue to the origin of the rest. Bearing in mind that the clay slates of Dent were not yet above the level of the ocean, we may picture these igneous centres pouring out the ferruginous stream of lava-like matter seawards, where it would meet the Carboniferous rocks tilted and fissured, and thus fitted to receive it. Then followed the Permian era, and after long ages the great final upheaval by which the outliers of the Lake District, Dent-fell, and Cold-fell, in the Whitehaven district, Blackcomb, in the Millom, Ireleth and High Haume, in the Furness district, were pushed through, tilting the Carboniferous rocks, and again fissuring them in all directions. This again would not be the work of a moment, but it would in all probability occupy an epoch giving time enough for denudations and the wearing out of the

subterranean water-courses or caverns which became filled with the hematites wherever circumstances were favourable."

Afterwards, Mr. Plant, quoting Professor Newberry, geologist for the State of Ohio, said: "Red hematite consists mainly of peroxide of iron, the ores of which have been plainly derived from limonite (brown hematite) by loss of the combined water. The famous Cumberland ore of England is a typical example of this variety. This was once a hydrated sesquioxide deposited from water in concretionary masses, and having a fibrous, radiated structure. Similar ore is found in various parts of the world; wherever, indeed, a limonite has been subjected to metamorphic action, by which its water is removed, hematite is found in concretions or botryoidal masses in sand or clay, filling crevices, pockets, and basins, or incrusting slopes—wherever, indeed, chalybeate waters have precipitated its iron. It is often associated with limestone rocks, because they are more easily than others dissolved by atmospheric water, so as to form caverns and galleries where the ore may accumulate, and also because the limestones contain much iron, and in the removal of the carbonate of lime by solution, the oxide of iron is left, and, to a certain extent, takes its place."

In the discussion of a paper by the writer, on "Hematite in the Silurians," published in the Quarterly Journal of the Geological Society, May, 1876, the late Mr. David Forbes is reported to have said, "that the direction of the vein-like deposits is due to their being formed in pre-existing fissures, into which hematite has been injected. When hematite is found in caverns it has been washed in by water."

It will have been noticed that all these explanations, as well as that given by Professor Harkness and Sir Roderick Murchison, in their remarks upon the age of the deposits, require the existence of caverns and fissures in which the ore could accumulate. But those who have followed carefully the previous remarks on the inner nature of the deposits will probably by this time be convinced that the deposits were not formed in either caverns or fissures. Take Fig. 1, Plate XXXI., for instance. It must be clear to everyone that the ore shown there could not by any possibility have been formed in a cavern. The thin bed of shale *f* running through the ore also passes without interruption right on into the side rock *c* and *c'*; in fact, it is interbedded with the limestone, and therefore must have been formed at the same time. Now, such being the case, it is evident that the ore which this parting intersects cannot have been thrown down in a cavern previously formed in the limestone, for if so, this thin parting, being now in the same relative position to the surrounding rocks as it was when first deposited, must have stretched across that cavern, and must consequently

have been able to stand without intermediate support across an opening five or six fathoms wide. Such a thing is, however, altogether impossible, for it must be evident to anyone that this thin parting could not possibly stand for a moment if the support was taken from it, as it must have been if it had spanned a cavern. Besides, it has already been seen that the ore was preceded by the faults, so that the shale parting *f* would receive no support from the rocks on the west side of the deposit, as it had then no connection with them, having been severed sometime previously by the fault. It must, therefore, have stood out from the side of the cavern like a cantilever. Such a thing is, however, quite impossible; so that it may be said with certainty that the ore in question was not deposited in a cavern. In the author's paper "On the Hematite Deposits of Whitehaven and Furness," it was shown that the same thing held for a deposit at Eskett Park; and the same thing is also shown by Fig. 3, Plate XXX., for the Salter Hall deposit. Fig. 2, Plate XXX., and Figs. 2 and 3, Plate XXXI., seem equally conclusive, that the deposits in which they were seen were not formed in a cavern. The shale nests and partings in the ore shown in these sections were evidently formed before the Carboniferous limestone had been disturbed, since the laminations of the shale in each case are parallel to the bedding of the rocks surrounding the ore. But it has already been seen that the ore was not deposited until after the limestone had been tilted and faulted. It is therefore clear that these nests and partings existed before the ore was thrown down, which shows that it could not have been laid in a cavern, or the shale nests would have been floating in mid-air. This conclusion is further extended by Plate XXVII., Fig. 1, Plate XXIX., and Figs. 1 and 2, Plate XXXII., where the ore has a shale "roof." No one at all acquainted with such-like deposits could for a moment suppose that the ore there shown could by any possibility have been deposited in a cavern. If at the present time in working the ore but a few square yards of these shale "roofs" be left unsupported, they very soon fall away. How could they have stood, then, before the ore was deposited as the "roofs" of immense caverns several acres in extent? It will be seen by an examination of the sections that these shale beds could not by any possibility have been deposited after the ore, for they are interbedded with the limestone, and consequently contemporaneous with that rock. Even deposits with strong stone "roofs" like that at Parkside, could not have been formed in a cavern. Anyone who has gone through the Peak Cavern in Derbyshire, which is the largest cavern in England, must have been struck by the immense number of limestone blocks which have fallen from the roof,

and now lie in piles upon the floor. Yet the size of the largest chamber in that cavern is, as it were, a mere "lough" compared with that which would be necessary to hold the Parkside deposit; in fact, it is not one-fortieth of the area. Then, the great regularity of the "roof" of the Parkside deposit, and the absence of roof-stone fragments on the "floor" (both contrasting strongly with the Peak Cavern) prove conclusively that that deposit is not a filled cavern.

What has been shown for some of the deposits is equally certain of the others, as could easily be shown were it necessary to multiply examples; so that it may be with every confidence asserted that at any rate the ore in the Carboniferous limestone was not deposited in caverns.

That the Millyeat ore is not a cavernous deposit will probably be admitted by all, notwithstanding its great resemblance to the deposit shown in Plate XXVII., which would generally be looked upon as having been formed in a cavern.

It will be as well next to see how far the idea about caverns and fissures is supported by the deposits in the Skiddaw slates and the Eskdale granite. It has been seen that the ore in both these rocks does not occur continuously in the veins, but that each vein consists of a number of "bunches" or "bellies" of ore, which are connected by what the miners call a "leader." Many of these "bunches" present an area of several hundred square yards when viewed in longitudinal section, as will be seen on reference to Fig. 2, Plate XXII. Now, in extracting the ore, especially at Kelton Fell and Knockmurton, the miners find it necessary to use a quantity of timber in order to keep up the "hanging cheeks." When "stoping" they cannot leave many yards square of the "cheek" unsupported, or it would very soon fall away. How could it have ever so stood, then, for hundreds of yards whilst the ore was being deposited, if it was deposited in an open fissure? Clearly it must have fallen away. That it has not done so is a proof that the ore was not deposited in a fissure. Besides, the section given in Fig. 1, Plate XXIII., bears no resemblance whatever to a filled fissure; yet many similar forms may be found in these veins.

The same thing cannot be shown so directly in the Water Blean ore, but the author's impression is that it, like the others, was not deposited in caverns, as will appear further on.

The effect of the foregoing conclusions is to show the inadequacy of all those attempted explanations of the origin of these deposits which involve the assumption of pre-existing caverns and fissures; that is to say, of all the explanation hitherto given by other writers. Those, however,

who have not witnessed the facts on which they are based may fail to feel their full force, so that it may not be undesirable to look at the question from another point of view. The fact which chiefly inclines writers and thinkers to the idea that these deposits are filled caverns and fissures is that they present external forms exactly similar to what they would have had if the ore had actually been placed in such receptacles; but it must not be forgotton that similarities are not identities. Moreover, it will be shown further on that precisely similar forms might be imposed upon the deposits by an entirely different process, yet one which is consistent with the remaining facts. The only other feature of the deposits that has been put forward as suggesting that they are filled caverns is that sometimes in working the ore the miners strike into a "lough" every side of which but that against the ore is limestone or "whirlstone." This, it is said, is part of the cavern that has not been filled. Now, if these "loughs" always occurred at the top of a deposit, there might be some force in the assertion; but, seeing that they are found at the bottom and sides as well, this argument is much weakened, for those at the lower levels would surely have been filled.

Having shown that the ore could not possibly have been deposited in caverns and fissures, and thereby exposed the insufficiency of previous explanations, it may seem unnecessary to follow them further; but, in order to show their general incompetence, the writer will make a few observations on the suggested modes in which the caverns and fissures were filled. Mr. Binney and Mr. Brockbank are of opinion that the ore is of volcanic origin, and that it was either injected into the places where it is now met with, through fissures immediately below, or it was first mingled with the waters of the sea and then thrown down as a sediment. Referring to Fig. 3, Plate XXII., and its description, it will be seen that everything in the vein is arranged in lines parallel to the "cheeks," as shown by the kidney ore *c''*. In the veins at Kelton and Knockmurton the same thing is seen. Now, sedimentary deposits do not take place in this way; they seek the lowest level possible. Moreover, no deposits are known which are formed on such steeply-inclined and overhanging faces as the "cheeks" of veins but chemical precipitates. That the ore was not injected directly from below into fissures is clearly shown by the gash-like form of the veins, the ore generally becoming less and less as it goes deeper. The reverse would have been the case had the ore come from below, for as the distance from its source increased, the work to be done by the ore would be increased too, and consequently the available energy would become less and less; so that as the ore moved forward its dimen-

sions would have to be gradually reduced. Thus it would happen, that if the ore had been injected from below it would have become thicker in depth; but as a matter of fact exactly the reverse is the case. Again, it surely is to be expected that there would be present some evidence of the calcining effect of these masses of molten matter, such as a hardening of the enclosing rocks; but in fact this is not so, but the reverse. So that it may be taken for granted that the ore in these veins was not deposited in a molten state, nor indeed as a sediment from water, for the reason given above. Neither was the ore in the Carboniferous limestone deposited in either of these ways, as is shown by the existence in it of fossils belonging to, and in some cases consisting of, that rock. Besides, the growing together of the limestone and ore in both these deposits, and that at Water Blean in the Coniston limestone, is quite opposed to either of the above explanations.

The views of the late Mr. David Forbes, so far as they can be gathered from his few remarks on the subject, appear to have been somewhat similar to those of Mr. Binney and Mr. Brockbank, so that it is not necessary to notice them separately; neither is anything special found in the opinions of Professor Newberry, Sir Roderick Murchison, and Professor Harkness. After these preliminary remarks, the author will proceed to give his theory.

It is known that when certain material elements, or certain combinations of those elements, are brought into contact under certain conditions there takes place between them a chemical reaction. For instance, if a piece of chalk is dropped into a solution of perchloride of iron, there at once sets in a reaction between them; part of the chalk is dissolved, and a red precipitate thrown down in its place. In time the chalk would disappear altogether, and nothing be left but this red precipitate. Now, that seems to be the process by which the hematite deposits were produced. The limestone, the slate, and the granite were each attacked like the chalk in the above experiment by a solution of iron, by which parts of them were removed and peroxide of iron thrown down in place thereof. Applying this explanation first to the limestone deposits, and especially to that shown in Fig. 1, Plate XXXI., and supposing that *d* and *d'* were originally beds of limestone with the shale parting *f* between them, and that by a process similar to that seen in the above experiment, these limestone beds were replaced by ore, the reason why the shale parting has never fallen away becomes apparent; for of course it would never be left unsupported, for as the limestone was taken away in solution the ore would be thrown down in its place. The same explanation shows why

the shale partings in the ore in Figs. 2 and 3, Plate XXX., and the shale "roofs" in Plate XXVII., Fig. 1, Plate XXIX., Figs. 1 and 2, Plate XXXI., and Figs. 1 and 2, Plate XXXII., have not fallen away. It shows, too, how the nests of shale in Figs. 2 and 3, Plate XXXI., which certainly were formed before the ore, have come to be in the apparently anomolous position in which they are found. As already stated, these nests must have been deposited before the rocks were tilted, and therefore before the ore was deposited; for that did not take place until the rocks had assumed very much of their present position. The shale must have been deposited along with the limestone, but offering, as it would, a greater resistance to the iron solution, the limestone around it has been removed and replaced, whilst the shale has remained but very little altered. To some it may appear difficult of belief that the shale could be deposited in such curious nests contemporaneously with the limestone; but these are referred to the section shown in Fig. 4, Plate XXXIII., which was sketched by the writer in the Salter Hall Mines.

It is, however, apart from this section, equally difficult to see how the nests could have been formed at the same time as the ore was deposited; so that no peculiar difficulty stands in the way of the replacement process, because it is impossible to show how such nests originated. Again, it will be seen how it is that the "roof" of such deposits as that at Parkside has not fallen; and also why only those deposits in the Third, Fourth, Fifth, and Bottom Limestone have shale partings. The First and Second Limestones, it will be seen by reference to the table, page 113, are not split up by partings like those below; so that no partings could be expected in the ore which had replaced those limestones.

The north and south direction of the deposits, when not interfered with by east and west faults, the occurrence of "guts" in the "roof" of such deposits as that at Fletcher Pit and the "rolls" in the "floor" of the Parkside deposit, as well as the general cavern-like form of the deposits as a whole, can each and all be satisfactorily explained on the supposition of a replacement process. At one time or another the author has examined nearly all the principal caverns in England, with the view of seeing what light they threw upon these hematite deposits, and invariably found that the different chambers of those caverns are hollowed out on the lines of jointing, sometimes following one set of joints and sometimes another; but the largest chambers were along those joints which run nearly north and south. This may be well seen in the Peak Cavern, in Derbyshire, the three largest chambers of which—the Victoria chamber, the great chamber, and the chamber at the entrance where the twine spinning is

carried on—are on the line of the north and south joints. Then, again, in the Blue John Mine, in the same county, the beautiful chamber known as Lord Mulgrave's dining-room, and the still larger chamber at the end of the cavern, are both on the line of the north and south joints. So also are the largest parts of Poole's Cavern, near Buxton. In the Brixham Cavern, in Devonshire, the correspondence of the different chambers with lines of jointing may be very distinctly seen. It is also very well displayed in Kents Hole, and in the author's paper "On the Hematite Deposits of Whitehaven and Furness" the same was shown to obtain in a cavern at Stainton, in Furness. The explanation is probably this: that carbonated water has gained access to the limestone along the joints, and that it has dissolved the limestone, particle by particle, on those lines, and afterwards carried it away until at length the widening joints united and formed the present caverns. The action of a solution of iron such as has been named would just be the same, only that as the limestone was dissolved and carried away, peroxide of iron would be thrown down in its place. Thus it may be seen how it is that the "guts," the "rolls," and the deposits as a whole are parallel to the joints. But why they keep to those that are nearly north and south cannot be explained so clearly, unless it is that the joints having this direction are stronger and more persistent. That would certainly account for it, and may probably be considered as the correct explanation, for as a matter of fact the north and south joints are more persistent; but still east and west caverns are found, so that east and west deposits of iron might with reason have been expected. Of course very much will depend upon the manner in which the acidulated water obtains access to the rocks; and the author hopes to be able to show further on, that it was just this which determined the parallelism of the deposits.

The growing together of the ore and stone is also explained by the replacement process. Being an operation which requires some time for its completion it will of necessity only be complete where that time has been sufficient. From there to the unaltered stone it will be less and less complete, that is to say between the ore and stone there will be a sort of "No man's land," occupied partly by stone and partly by ore, the one increasing as the other diminishes, and each retaining less of its peculiar character as the distance increases from its native land. The greater resistance presented to the iron solution by the siliceous portions of the limestone is no doubt the reason that they were left in masses in the deposits as now found. The form of these siliceous masses would doubtless in many cases affect the shape and direction of the deposit, as the iron

solution would act more easily on the limey portions than on them. This is probably the reason that the sides of the ore sometimes take very peculiar and irregular turns. For the same reason the shale and sandstone forming the roof and sole in many deposits would not be replaced. The softer nature of the ore adjoining some shale beds is probably due to the admixture of shale with the limestone which the iron replaced, for the change from limey, to argillaceous and siliceous conditions would no doubt be gradual. The shale thus incorporated with the limestone not being so easily acted upon, as the latter rock, remains now mechanically mixed with the ore, rendering it soft in proportion to the quantity of shale there is.

The laminated nature of some of the ore near the stone, and the alternate hard and soft beds sometimes met with, are both easily explained by the replacement process, as is also the occurrence in the ore of fossils—some converted into hematite—belonging to the Carboniferous Limestone. These fossils, like the shale beds in the ore, are an insurmountable obstacle to all other explanations, but to this they offer no difficulty whatever; in fact, they are another proof of its truth and theoretical* nature.

In applying this explanation to the Millyeat ore, the nature of the bed before the replacement was effected cannot positively be pointed out, but from the thin irregular layers of limestone found in it, and the large quantity of lime which exists in a diffused state in some of the poorer ore, it seems extremely probable that it was originally a limestone. This is the more likely, as the horizon is about the same as that of the Spirorlis Limestone of the Upper Coal-measures of Ayrshire and Lancashire, etc. With a view of testing this supposition the author has several times looked for Spirorlis in the ore but as yet has not succeeded in finding any. That, however, is only negative evidence and does not go for much, if anything at all; but that the bed was originally limestone there seems to be very little doubt. When the rocks rose from beneath the waters of the Carboniferous sea, after the deposition of the Whitehaven sandstone, denudation commenced its work of destruction on their upturned edges. This continued without intermission until it was terminated by the submergence which immersed the rocks in the reddened Permian sea. Then it was that the replacement of the bed of limestone by the hematite was accomplished. This, doubtless, is the age of all the other ore too, that is to say, early Permian.

The veins in the granite and Skiddaw slate are also more easily explained on the assumption that they were formed by replacement, for then the difficulty of keeping up the hanging wall, whilst the ore was being deposited,

* This word is not here used as signifying opinion, a sense in which it is too often used.

has not to be contended with as is the case when also supposed to have been deposited in fissures. Besides, by this supposition, there is an easy explanation of the occurrence of the ore in such forms as shown in Fig. 1, Plate XXIII., of those pieces of slate in the veins of Kelton and Knockmurton which are so largely impregnated with iron as to be almost indistinguishable from some of the more earthy-looking ore and of the transition from granite to ore, described as sometimes occurring in the veins of Eskdale, whilst every other feature of these veins may be more simply explained by replacement than on the assumption that they are filled fissures. They are less than the deposits in the Carboniferous limestone for the simple reason that the rocks in which they occur are more insoluble.

In extending the explanation to the Water Blean deposit a difficulty is met with. Mr. Binney (as already mentioned) states that he has seen several fossil coal plants, converted into hematite, which had come from this deposit. Now if the ore had replaced the original limestone, the supposed coal plants must have been imbedded in that limestone; that is, however, scarcely possible, seeing that the limestone is of Silurian age, so that it must be concluded either that coal plants have not been found in the deposit at all; or, if so, that it was not formed by replacement. The author chooses the former alternative, for, as already stated, he does not believe that the structures referred to by Mr. Binney are plants of any kind, but simply what is known as "ring ore," whilst the growing together of the limestone and ore, similarly to what is seen in the Carboniferous Limestone deposits, convinces him fully that this deposit, like the others, was formed by replacement.

It is not intended to say much as to the source of the ore. That it was primarily volcanic will be admitted by all without hesitation. The question of greater interest is, how was it introduced immediately to its present positions? Referring back to the time when, after the denudation of the Whitehaven sandstone, the rocks were sunk into the Permian sea, and supposing that the subsidence continued until the highest mountain tops were covered, which, from what has been already stated, was the time that the last movement of the east and west faults took place. In all probability there would be a movement of the north and south faults as well, but as already seen it was not their last. Now, if it can be supposed that the perchloride of iron was breathed through these moving fractures and dissolved in the waters of the sea, all the conditions necessary for the production of the West Cumberland hematite deposits are present. That too much is not assumed will be admitted when it is remembered how frequently this salt of iron is found among volcanic emanations at the present time.

No sooner then would the iron solution be formed than a reaction would set in between it and the rocks. In the Carboniferous limestone the irony water would doubtless circulate freely along the lines of faulting, the limestone would be dissolved, and iron thrown down in its place. Thus the direction of the faults would in a great measure determine that of the deposits, although there might occur cases such as that at Lord Leconfield and Wyndham Pit, where the iron would gain access to the limestone more easily along the north and south joints than on east and west faults. The deposits in the granite and slate, as well as those in the Coniston limestone and Upper Coal-measures, are in this way also easily explained. The proximity of the ore to the eroded surface of the pre-Permian rocks and the localisation of the deposits are both necessary consequences of the actions involved in this explanation. The gaseous emanations would not be dissolved until they met the water near the surface of the rocks, so that it would be there that the reaction between the iron solution and the rocks would take place. The lines of pre-Permian faulting being the passages along which the iron travelled upwards from its source to the superincumbent waters, it is to be expected that the absence of faults would indicate the absence of deposits. Now a careful examination of the district embraced in Plate XIX. shows that this is so. Then again, in the hitherto barren country between Rowrah and Ullock, there is a great absence of faults, the only large one, not having yet been proved, as to whether there is ore by the side of it or not.

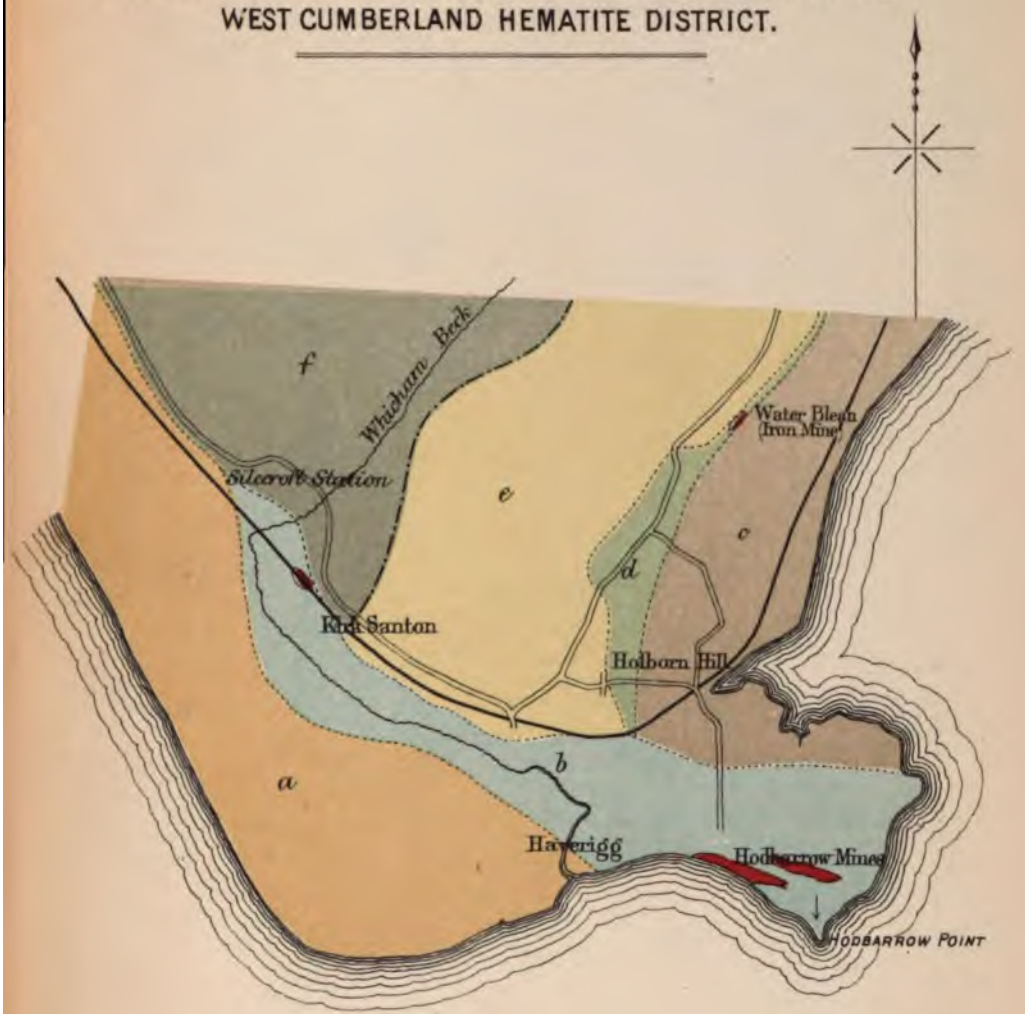
Those who have read the author's previous papers on this subject will notice some changes of opinion in this, the most important being as to the source of the iron and the form in which it was introduced to the rocks. The replacement process which was previously applied to some deposits only is now extended to all. When first the writer began to study these deposits the idea of caverns and fissures was adopted. Very soon, however, its incompetence to explain the facts became apparent. Accumulating observations spoke stronger and stronger against it, and at length completely annihilated it. In its place has been adopted, as more agreeable to the facts, the idea embodied in this paper.

In conclusion the writer would extend this explanation to the Furness deposits, to the Ipstones hematite, and that found in the Carboniferous limestone near Newhaven House, in Derbyshire. The "growing together" of the ore and limestone there is exactly the same as it is here. The explanation also seems sufficient for the ore found at Whitechurch, in Glamorganshire, mentioned in Part III. of the Iron Ores of Great Britain. The writer there says—"This bed, situate in the Lower Limestone shales,

is made up entirely of remains of encrinites. These habitants of an ancient sea seem to have collected in some quiet spots out of the reach of currents and to have had the power of secreting iron to a great extent, with the lime necessary for their support—tracing the same bed west and east, it becomes gradually changed into an encrinital limestone." It seems, then, that if it is supposed that part of the limestone has been replaced by iron, a very simple explanation of these facts has been arrived at. The limestone and hematite deposits in the Devonian limestone near Brixham, in Devonshire, and in the granite and Devonian slate, in Cornwall, would be explained in the same way. The deposits at Galena, at Alston Moor, and in Derbyshire, seem to have had a similar origin, as well as many other deposits which need not now be mentioned.

To illustrate Mr J. D. Kendall's paper "On the Hematite deposits of West Cumberland."

ENLARGED GEOLOGICAL MAP OF THE SOUTHERN PORTION OF THE WEST CUMBERLAND HEMATITE DISTRICT.



REFERENCE.

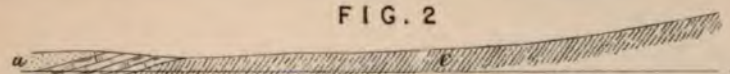
Permian	St. Bees Sandstone	a
Carboniferous	Carboniferous Limestone	b
Silurian	Coniston Flags & Grits	c
	Limestone	d
	Borrowdale Series	e
	Skiddaw Slate	f
	Hematite	
	Fault	

Scale 1 inch to a Mile.

Proceedings Mr E. J. of Mr M.E. 1872-73

To illustrate Mr. J. D. Kendall's paper "On the Hematite deposits of West Cumberland."

FIG. 2



Scale 1 inch to a Mile.

FIG. 1

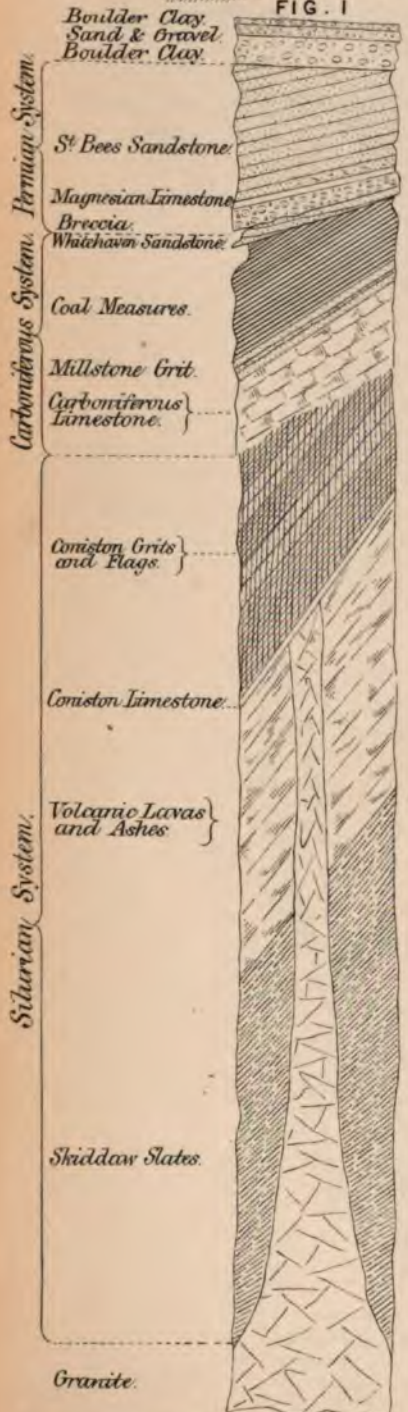
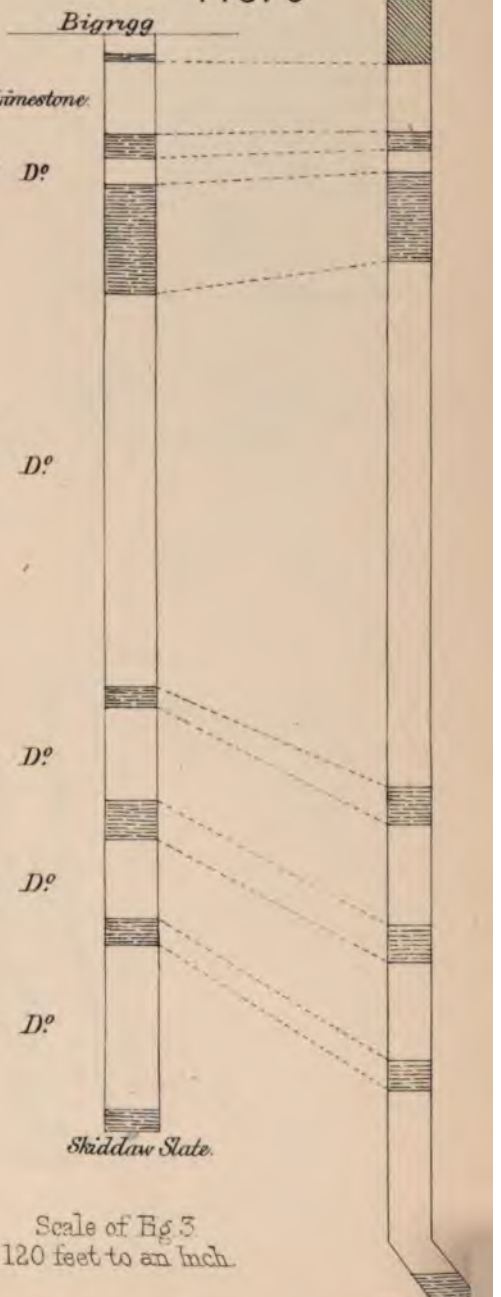


FIG. 3



Scale of Fig 3.
120 feet to an Inch.

Andᵗ Reid, Newcastle

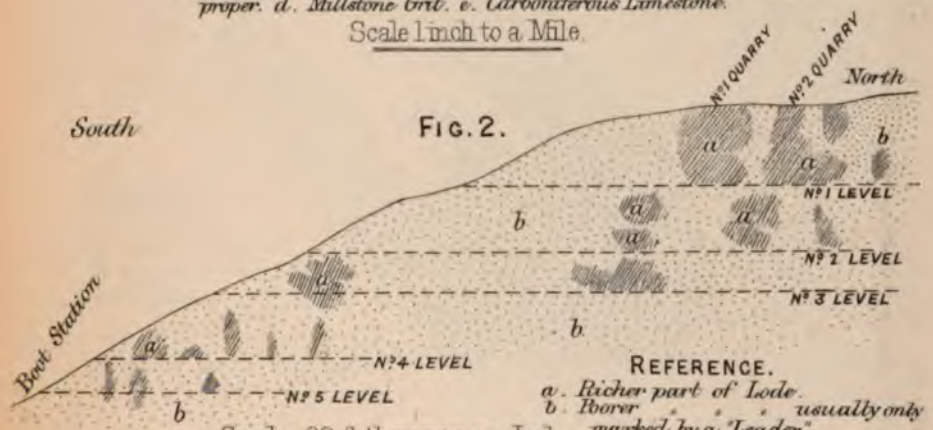
To illustrate Mr. J. D. Kendall's paper "On the Hematite deposits of West Cumberland."

FIG. 1.

a. St Bees Sandstone. b. Whitehaven Sandstone. c. Coal Measures proper. d. Millstone Grit. e. Carboniferous Limestone.

Scale 1 inch to a Mile.

FIG. 2.

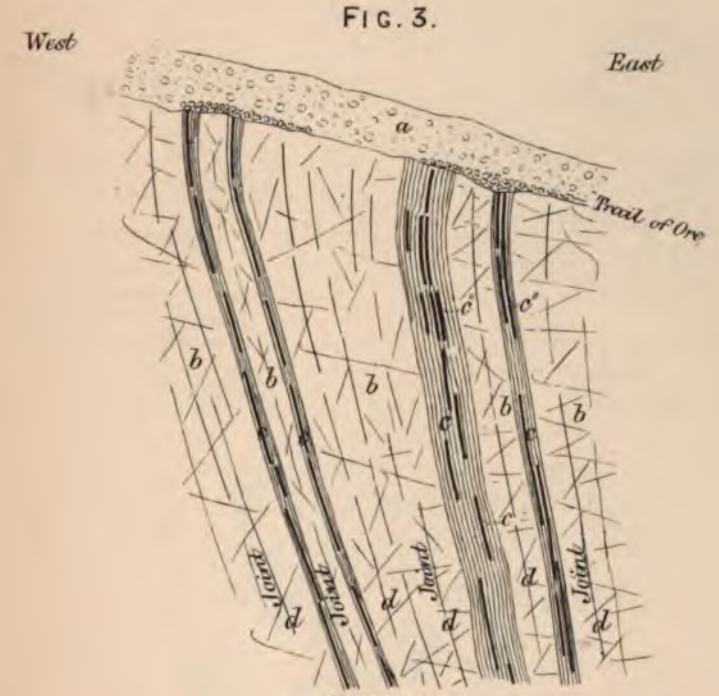


REFERENCE.

a. Richer part of Lode.
b. Poorer " " usually only marked by a "Leader."

Scale 60 fathoms to an Inch.

FIG. 3.



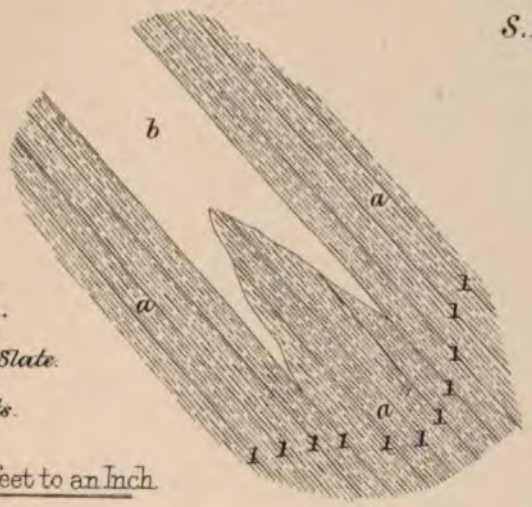
REFERENCE.

a. Boulder drift
b. Granite decomposed adjoining the Ore.
c. Hematite &c. c" Kidney Ore.
d. Joints in the Granite.

Scale 16 feet to an Inch.

To illustrate M.r J.D. Kendall's paper "On the Hematite deposits of West Cumberland."

FIG. 1.



REFERENCE.

a. *Skiddaw Slate.*
b. *Hematite.*
1. *Bed Joints.*

Scale 8 feet to an Inch.

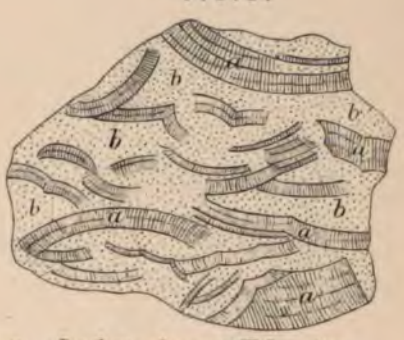
FIG. 2.

REFERENCE.

a. *Slate Cheeks of Vein.*
b. *Kidney Ore on Cheeks of Vein.*
c. *Lough filled with Quartz Spar.*
d. *Broken pieces of Kidney in centre of Vein.*

Scale 8 feet to an Inch.

FIG. 3.



a. *Broken pieces of Kidney Ore.*
b. *Brown Spar.*

Full Size.

FIG. 4.

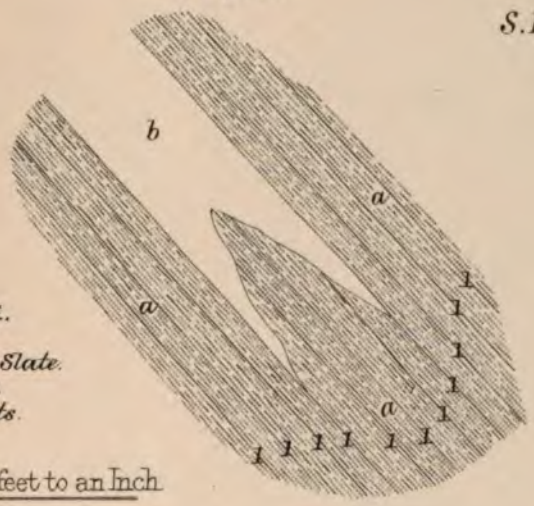
a. *Hard Hematite containing fragments of Slate b. Firmly embedded.*

Full Size.

To illustrate M.r J.D. Kendall's paper "On the Hematite deposits of West Cumberland."

FIG. 1.

N.W. S.E.



REFERENCE.

a. Skiddaw Slate.
b. Hematite.
1. Bed Joints.

Scale 8 feet to an Inch

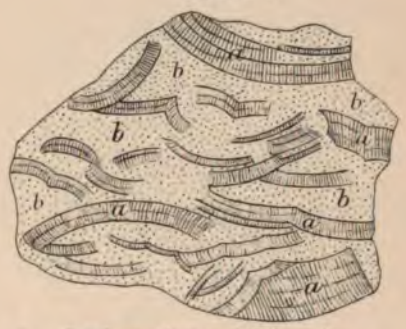
FIG. 2.

REFERENCE.

a. Slate Cheeks of Vein.
b. Kidney Ore on Cheeks of Vein.
c. Lough filled with Quartz Spar.
d. Broken pieces of Kidney in centre of Vein.

Scale 8 feet to an Inch.

FIG. 3.



a. Broken pieces of Kidney Ore.
b. Brown Spar.

Full Size.

FIG. 4.

a. Hard Hematite containing fragments of Slate b. Firmly embedded.

Full Size.

To illustrate M.r J.D. Kendall's paper On the Hematite deposits of West Cumberland.

FIG. 1.

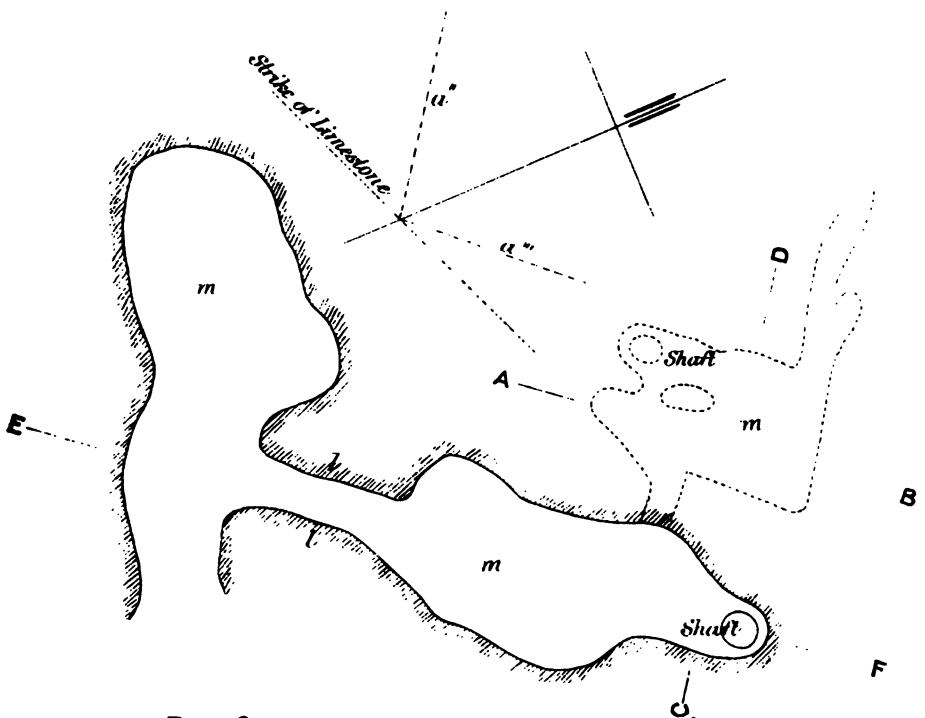


FIG. 2.

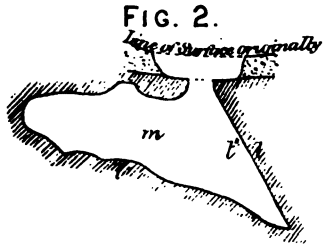


FIG. 3.

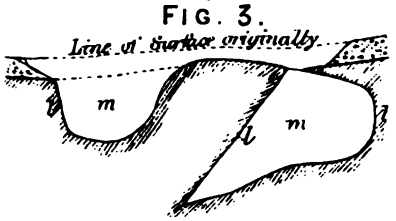
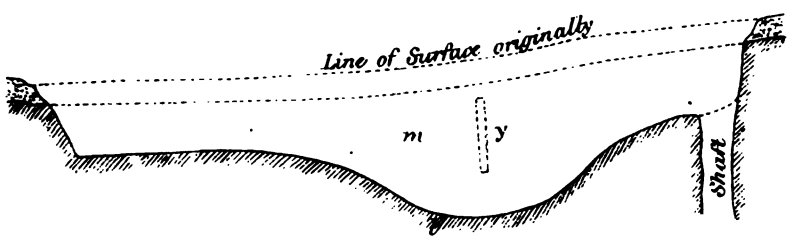


FIG. 4.



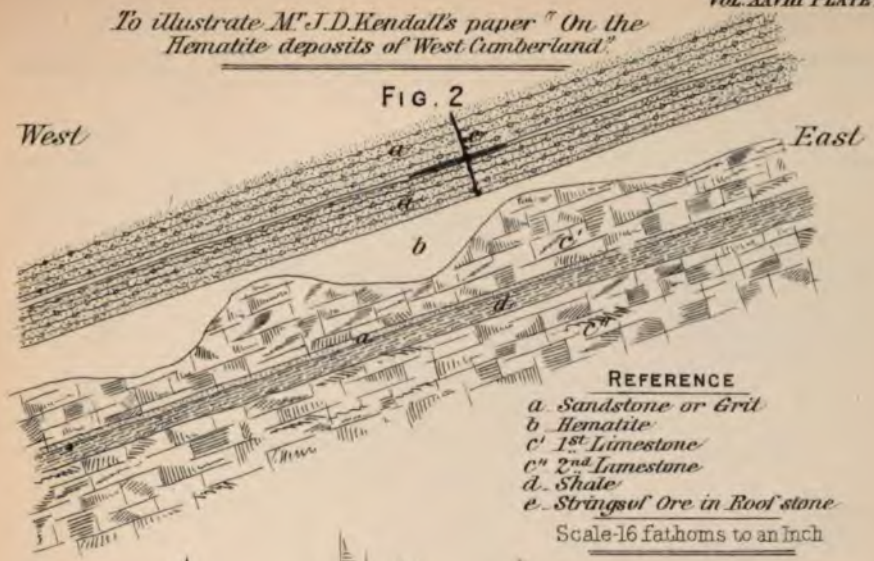
REFERENCE.

a.a. Direction of Joints intersecting the Limestone.
l. Limestone.
m Cavity from which Ore has been removed.

Scale 30 feet to an Inch.

To illustrate M.r J.D. Kendall's paper "On the Hematite deposits of West Cumberland".

FIG. 2

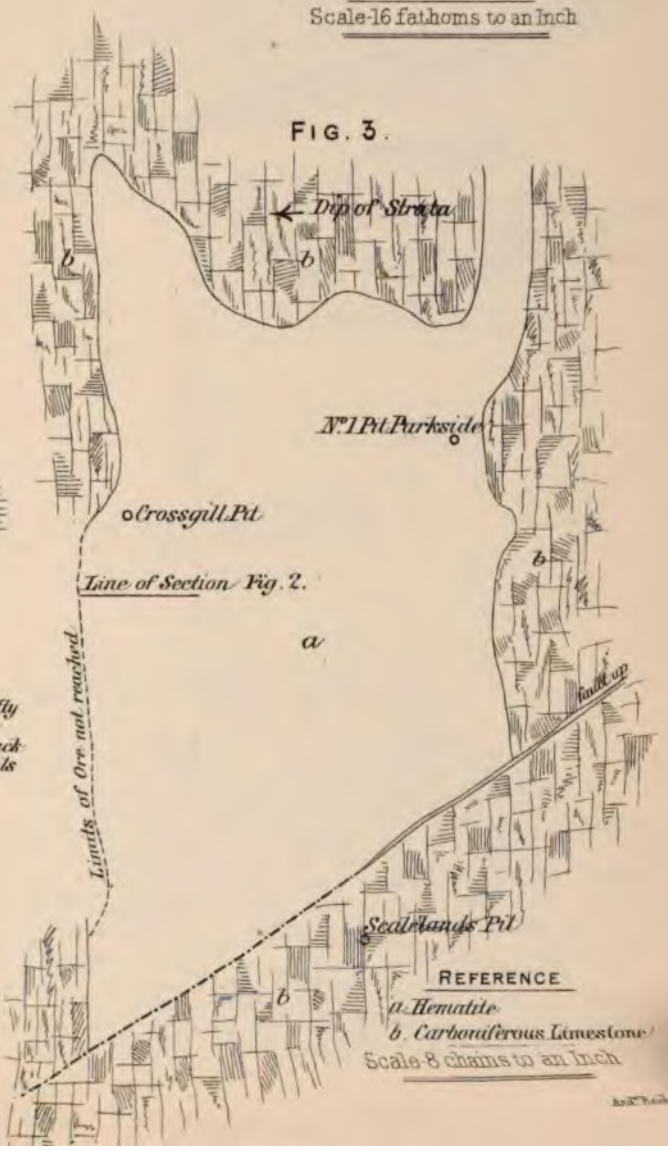


REFERENCE

a Sandstone or Grit
b Hematite
c' 1st Limestone
c'' 2nd Limestone
d Shale
e Strings of Ore in Roof stone

Scale-16 fathoms to an Inch

FIG. 3.



REFERENCE

a Hematite
b Carboniferous Limestone

Scale-8 chains to an Inch

FIG. 1

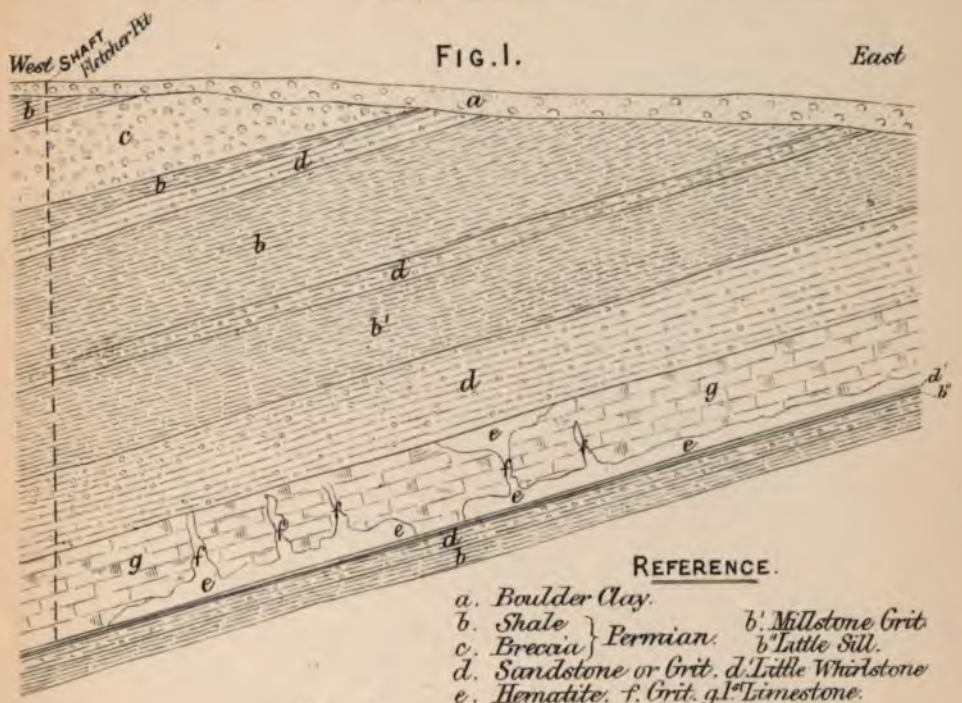
REFERENCE

a Massive Ore
b Kidney Ore
c Crystals of Calcite
d Partly Massive Ore and partly a soft brown substance like what is locally known as "Black mauck" and sometimes Crystals of Calcite.

Scale-Twice full size

To illustrate M^r J. D. Kendall's paper "On the Hematite deposits of West Cumberland."

FIG. 1.



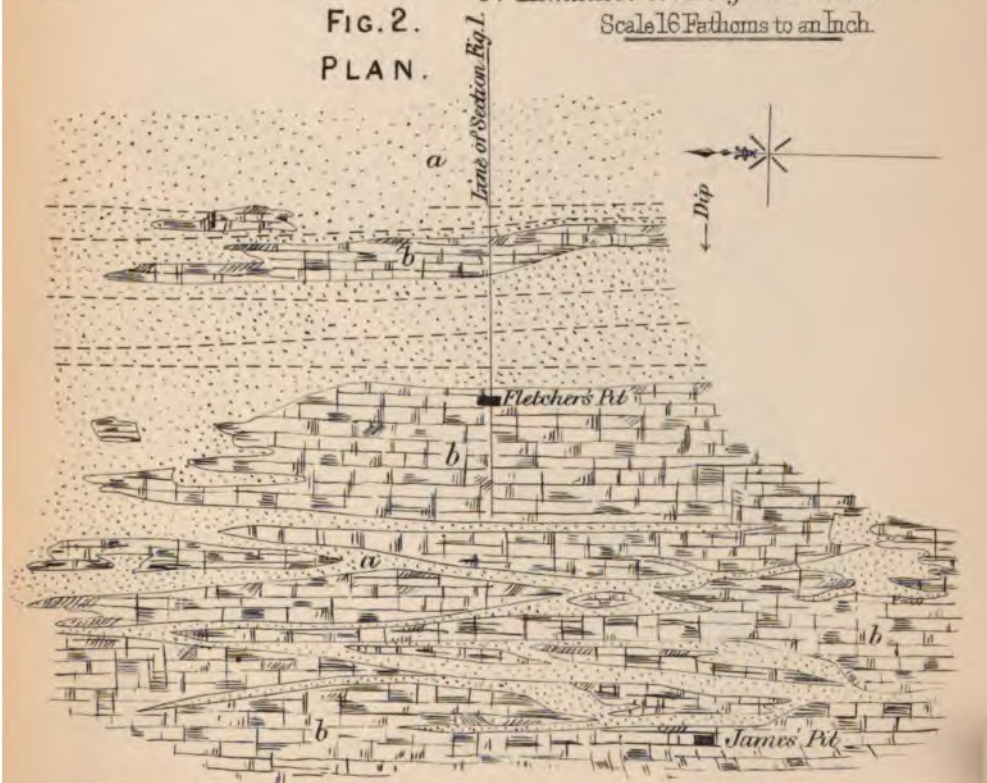
REFERENCE.

a. Boulder Clay.
b. Shale } Permian. b'. Millstone Grit
c. Breccia } Permian. b". Little Sill.
d. Sandstone or Grit. d'. Little Whinstone
e. Hematite. f. Grit. g. 1st Limestone.

Scale 16 Fathoms to an Inch.

FIG. 2.

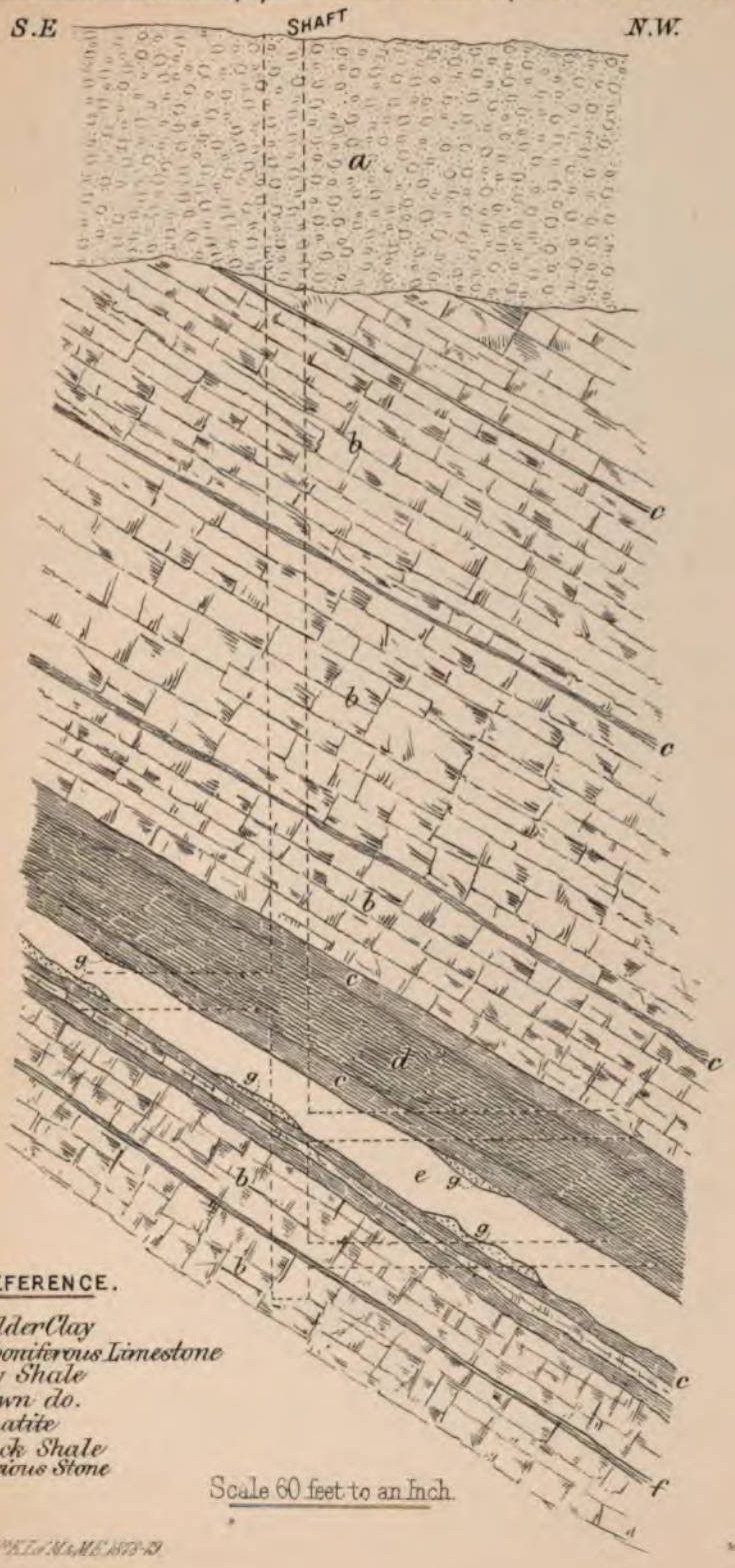
PLAN.



a. Hematite. b. Limestone
---- Outs of Hematite in Roof.

Scale 264 feet to an Inch.

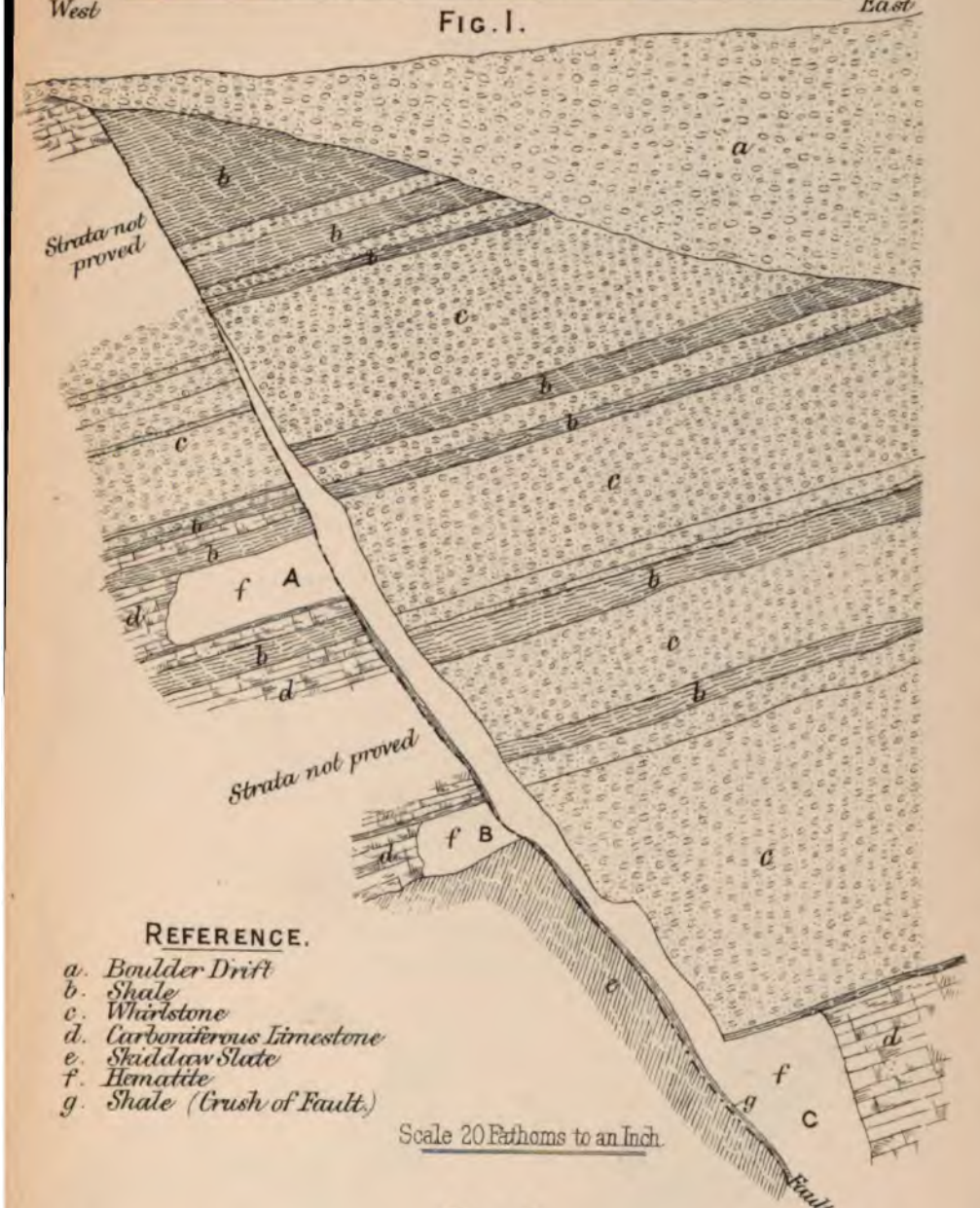
To illustrate Mr. J. D. Kendall's paper "On the Hematite deposits of West Cumberland."



To illustrate M.r J.D. Kendall's paper "On the Hematite deposits of West Cumberland."

West — East

FIG. 1.

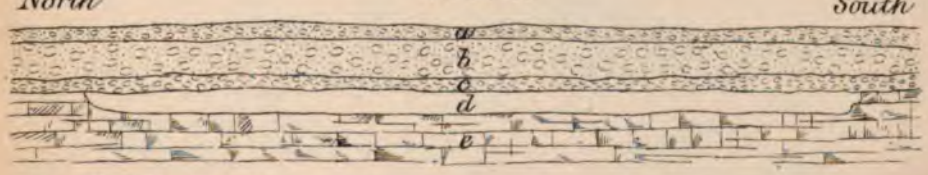


REFERENCE.

a. Boulder Drift
b. Shale
c. Whinstone
d. Carboniferous Limestone
e. Skiddaw Slate
f. Hematite
g. Shale (Crush of Fault)

Scale 20 Fathoms to an Inch.

FIG. 2.

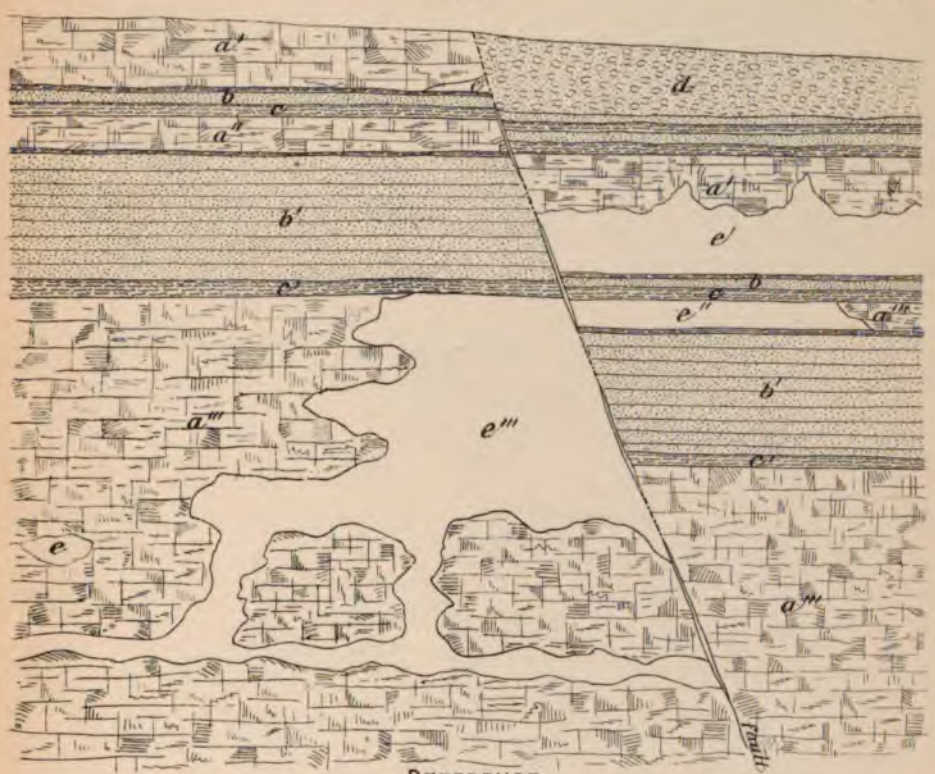
North — South

a Sand & Gravel
b Sand & Clay
c Gravel
d Hematite
e Carboniferous Limestone.

Scale 600 feet to an Inch.

Proceedings No. 2. Inst. M. & M.E. 1878-79.

To illustrate Mr. J.D. Kendall's paper "On the Hematite deposits of West Cumberland".

South — FIG. 1. — North

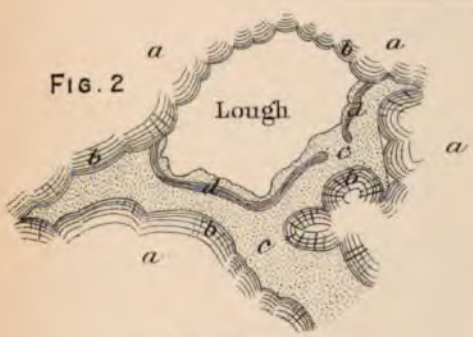


REFERENCE

a'. a''. a'''. — 1st, 2nd and 3rd Limestones respectively
b. b'. — Sandstone
c. c'. — Shale
d. — Boulder Drift
e'. e''. e'''. — Hematite in 1st, 2nd and 3rd Limestones respectively

Scale. 100 feet to an Inch

FIG. 2



REFERENCE

a. Massive Hematite
b. Kidney Ore
c. Brown Spar
d. Laminated Hematite enclosed in Spar

Scale. 1 foot to an Inch

FIG. 3.

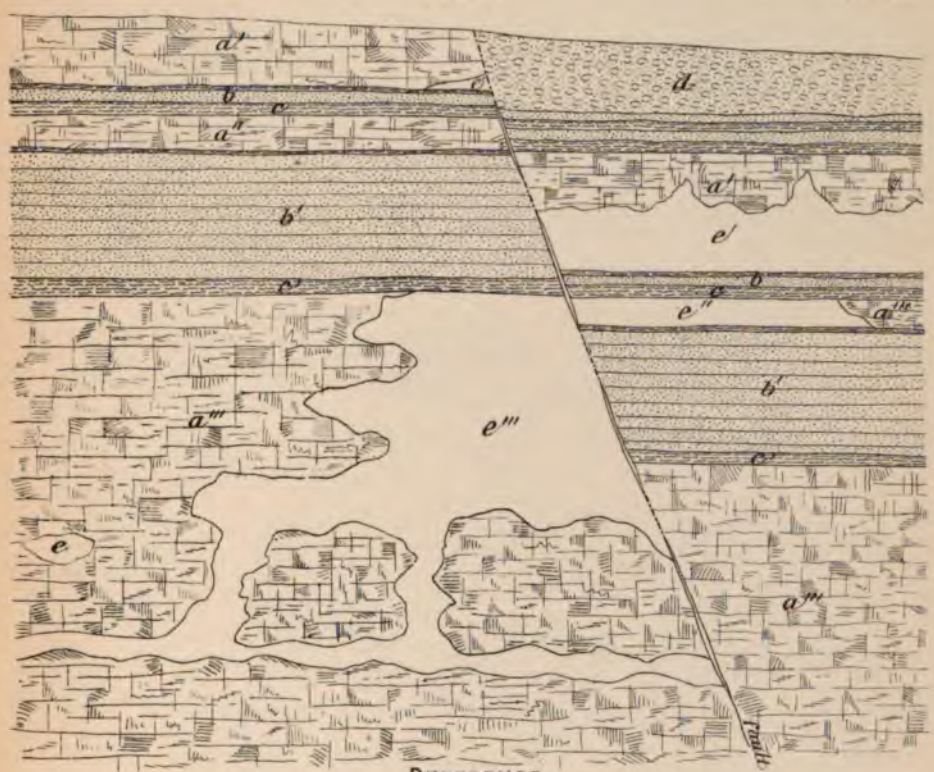
REFERENCE

a. Massive Hematite (laminated next the Spar)
b. Brown Spar

Scale. 2 Inches to a Foot

To illustrate Mr. J.D. Kendall's paper "On the Hematite deposits of West Cumberland".

South — FIG. 1. — North

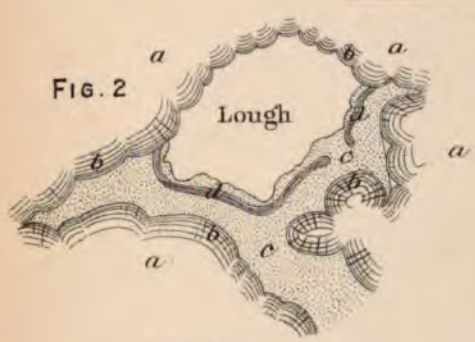


REFERENCE

$a'\ a''\ a'''$ — 1st, 2nd and 3rd Limestones respectively
$b\ .\ b'$ — Sandstone
$c\ .\ c'$ — Shale
d — Boulder Drift
$e'\ .\ e''\ .\ e'''$ — Hematite in 1st, 2nd and 3rd Limestones respectively

Scale. 100 feet to an Inch

FIG. 2



REFERENCE

a . Massive Hematite
b . Kidney Ore
c . Brown Spar
d . Laminated Hematite enclosed in Spar

Scale. 1 foot to an Inch

FIG. 3.

REFERENCE

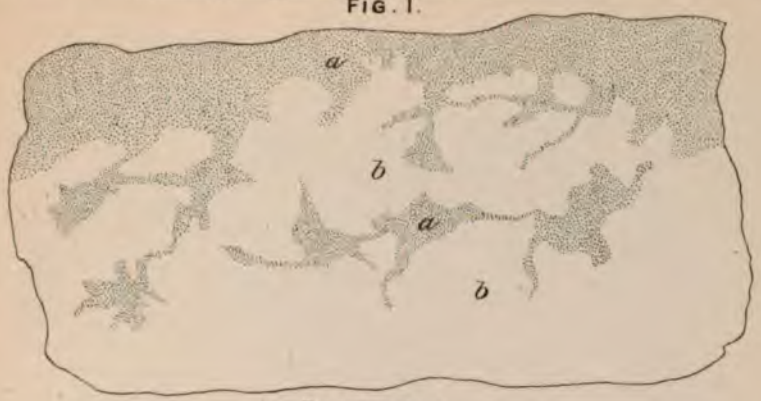
a . Massive Hematite (laminated next the Spar)
b . Brown Spar

Scale . 2 Inches to a Foot

Proceedings No. E.I. of M. & M.E. 1878-79.

To illustrate Mr. J.D. Kendall's paper "On the Hematite deposits of West Cumberland."

FIG. 1.



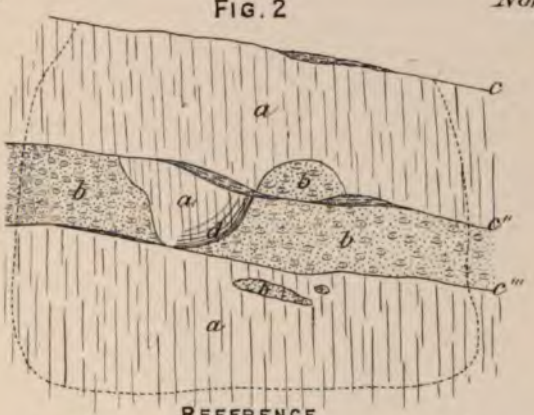
REFERENCE

a. Hematite (poor)
b. Silicious Stone

Full Size

South *North*

FIG. 2

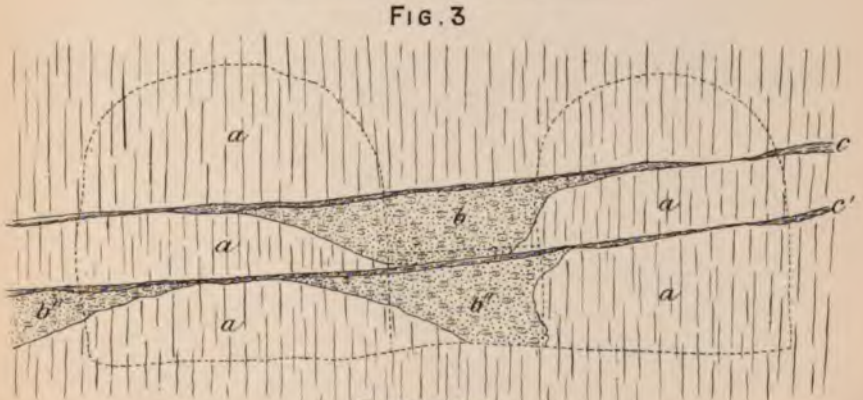


REFERENCE

a. Hard jointy Hematite laminated at d.
b. Whirlstone
c, c' c'' Shale partings

Scale 4 feet to an Inch

FIG. 3



REFERENCE

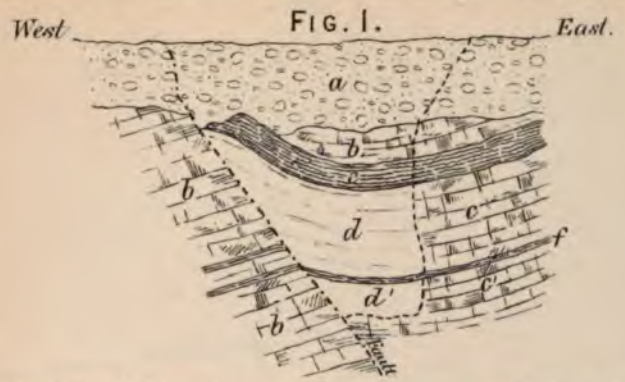
a. Hard jointy Hematite — b, b'' Whirlstone — c. c' Shale partings

The dotted lines shew the workings by which the Section was laid open

Scale 8 feet to an Inch

To illustrate M^r J.D. Kendall's paper "On the Hematite deposits of West Cumberland."

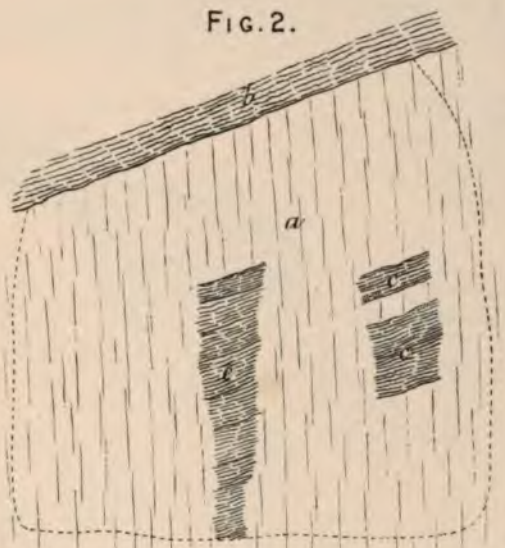
FIG. 1.



a. Boulder Clay. b. Limestone. c c'. Limestone very Silicious. d d'. Hematite. e. Red & Grey Shale. f. Grey Shale. The dotted lines shew the sides of the Openout.

Scale 40 feet to an Inch.

FIG. 2.



a. Hard Hematite intersected by vertical joints. b. Light Grey Shale. c Dark Grey Shale stained with Iron Ore in places. Dotted lines shew sides & Sole of working b forming the Roof.

Scale 4 feet to an Inch.

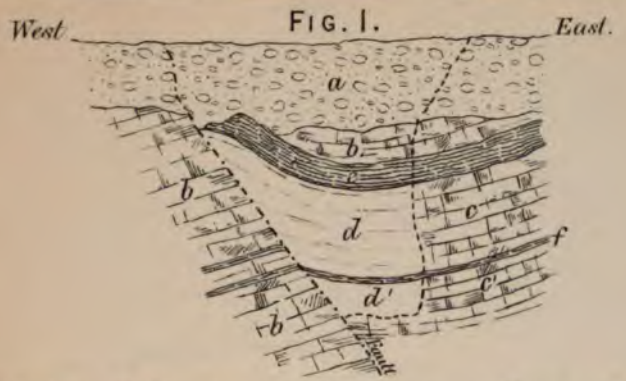
FIG. 3

a. Hard Hematite.
b. Brown Shale stained with Iron Ore.

Scale 4 feet to an Inch.

lustrate M^r. J.D. Kendall's paper "On the Hematite deposits of West Cumberland."

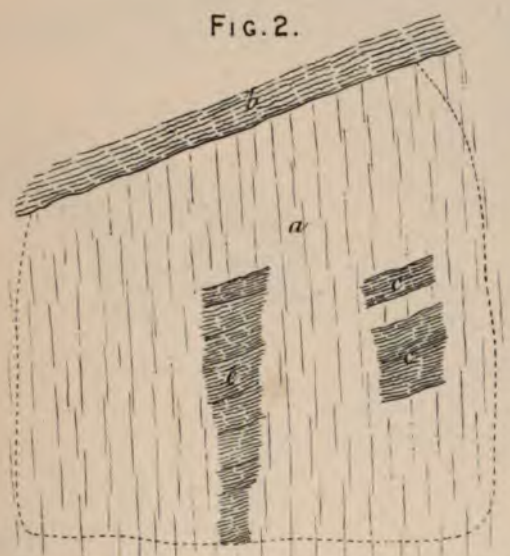
FIG. 1.



a. Boulder Clay. b Limestone. c c'. Limestone very Silicious. d d'. Hematite.
. Red & Grey Shale. f. Grey Shale. The dotted lines shew the sides of the Opencut.

Scale 40 feet to an Inch.

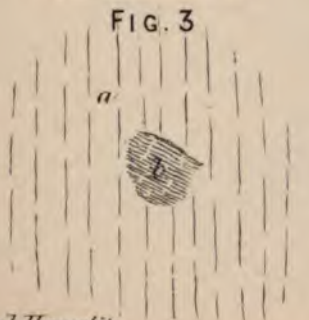
FIG. 2.



a. Hard Hematite intersected by vrtical joints. b. Light Grey Shale. c Dark Grey Shale stained with Iron Ore in places. Dotted lines shew sides & Sole of working. b forming the Roof.

Scale 4 feet to an Inch.

FIG. 3

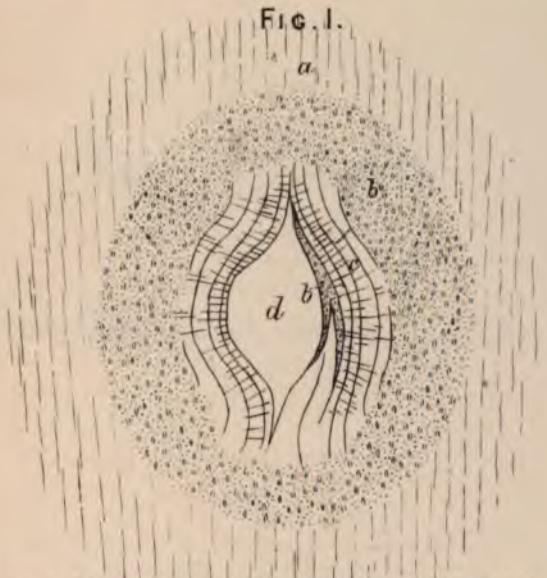


a. Hard Hematite.
b. Brown Shale stained with Iron Ore.

Scale 4 feet to an Inch.

To illustrate Mr. J. D. Kendall's paper "On the Hematite deposits of West Cumberland"

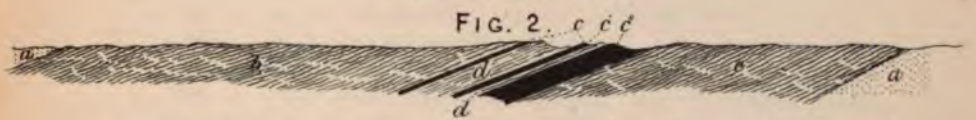
FIG. 1.



a. Hard jointed Hematite. b. Granular & Crystalized Hausmannite.
c. Gothite (foliated.) d. Soft Hematite (clayey)

Scale 1 inch to a foot.

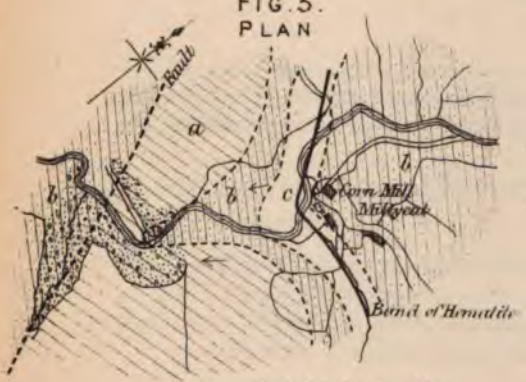
FIG. 2.



a. Grey Sandstone sometimes with a purple tint. b. Red Shale. c. c'. c''. Hematite 1, 3 & 11 Inches thick respectively. d. Purple Grey & Yellow Shale. (Clayey) e. Liver-coloured Shale.

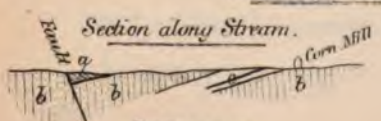
Scale 8 feet to 1 inch.

FIG. 3.
PLAN



Scale 6 inches to a Mile.

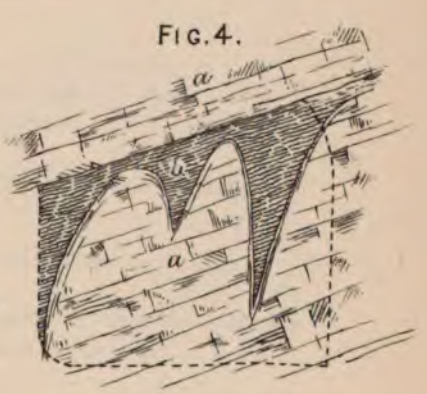
Section along Stream.



REFERENCE.

Whitehaven Sandstone
a. Permian Breccia
b. Grey Sandstone
c. Liver coloured Shale containing band of Hematite.

FIG. 4.



REFERENCE.

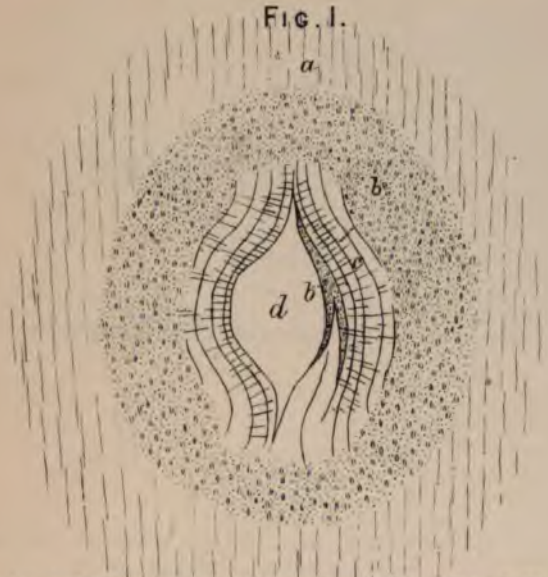
a. Hard Grey Limestone
b. Grey Shale with purple spots.

The dotted line denotes sides of drifts in which the section was exposed.

Scale 4 feet to an Inch.

To illustrate Mr. J. D. Kendall's paper "On the Hematite deposits of West Cumberland"

FIG. 1.



a Hard jointed Hematite. b. Granular & Crystalized Hausmannite.
c. Gothite (foliated) d. Soft Hematite (clayey)

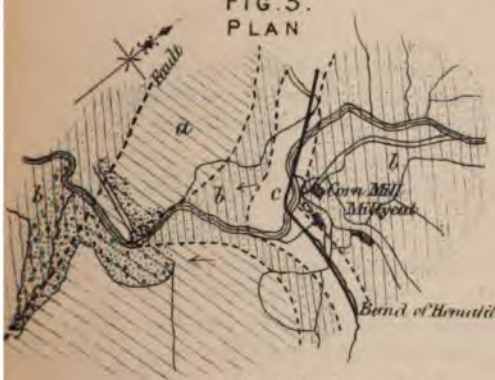
Scale 1 inch to a foot.

FIG. 2.

a. Grey Sandstone sometimes with a purple tint. b. Red Shale. c.c'.c'' Hematite 1, 3 & 11 Inches thick respectively. d. Purple Grey & Yellow Shale (Clayey) e. Liver-coloured Shale.

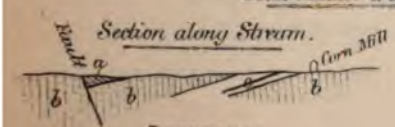
Scale 8 feet to 1 inch.

FIG. 3.
PLAN



Scale 6 inches to a Mile.

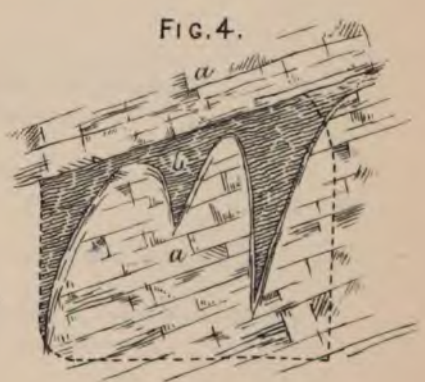
Section along Stream.



REFERENCE.

Whitehaven Sandstone { a. Permian Breccia
b. Grey Sandstone
c. Liver coloured Shale containing band of Hematite.

FIG. 4.

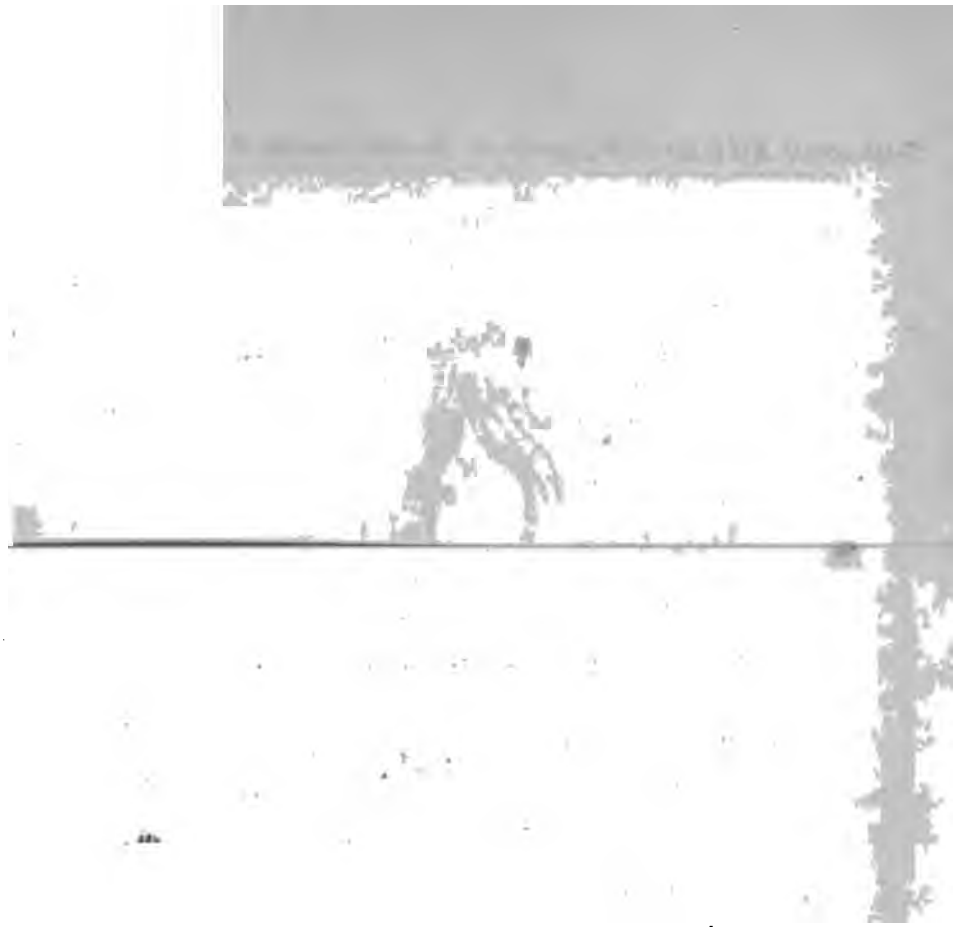


REFERENCE.

a. Hard Grey Limestone.
b. Grey Shale with purple spots.

The dotted line denotes sides of driftway in which the section was exposed.

Scale 4 feet to an Inch.



PROCEEDINGS.

GENERAL MEETING, SATURDAY, FEBRUARY 15TH, 1879, IN THE WOOD MEMORIAL HALL.

A. L. STEAVENSON, ESQ., IN THE CHAIR.

The SECRETARY read the minutes of the last general meeting, and reported the proceedings of the Council.

The following gentlemen were elected:—

ORDINARY MEMBER—

Mr. TOM PATTINSON MARTIN, Colliery Manager, Allhallows Colliery, Mealsgate, Carlisle.

ASSOCIATE—

Mr. LOUIS CLOVIS, 1, Borough Houses, Gateshead-on-Tyne.

STUDENTS—

Mr. A. B. BLAKELEY, Hollyroyd, Dewsbury.
Mr. H. CHILD, Whitkirk, near Leeds.
Mr. JOS. WM. PATTISON, Londonderry Offices, Seaham Harbour.
Mr. SEPTIMUS H. HEDLEY, Londonderry Offices, Seaham Harbour.
Mr. THOMAS SMITH, Leadgate, County of Durham.

The following were nominated for election at the next meeting:—

ASSOCIATES—

Mr. JOHN ELYOTT DOYLE, B.A., Lecturer in Natural Science, St. Peter's Terrace, Birmingham.
Mr. PATRICK DOYLE, C.E., F.G.S., Superintendent of Public Works, Surveys, and Mines, Perak, *via* Penang, Straits Settlements.

STUDENT—

Mr. JAMES KENNETH GUTHRIE, Ryton-on-Tyne.

The CHAIRMAN announced that the paper by Messrs. A. Freire-Marreco and D. P. Morison, "An account of some recent Experiments with Coal Dust," was open for discussion.

Mr. D. P. MORISON said, the paper was intended more as a theoretical commencement than as a practical following out of the subject. The authors thought that it would be advisable to bring the matter before the Institute, in order that the members themselves might have the opportunity, either in the discussion upon the paper or in subsequent papers, of bringing forward any practical facts in their experience bearing upon the matter. Since the publication of the paper they had received several communications from different parts of the country, giving instances where coal dust had ignited from blown-out shots or similar causes, as well as of accidents which had occurred in screens or other places where coal dust had been thrown upon fire or flame of some kind. There was no doubt whatever that a great many accidents had taken place in that way; and it would be very interesting if all these could be compiled together in a paper to follow up the humble effort which Professor Marreco and himself had made, in a theoretical way, to introduce the subject, which was one well worth attention; and, if they (the authors of the paper) were right in their conclusions, it was one of such importance as to make its special consideration highly necessary in all cases, but more especially where hot and dry seams were being worked. One suggestion which had been made in the matter was that, where practicable, especially in the main ways, the dust should be periodically watered; and another suggestion which was important, although in a less degree, was that no tamping of the shot holes should be made with slack or small coal, as the tendency of slack was to allow the shot to blow out and very likely to ignite the dust with which it came in contact.

Mr. W. LOGAN said, that in grinding coals by a Carr's disintegrator, for making coke, in cases where the disintegrator is closely covered over, and the ground coal falls into a large hopper underneath, the air in the hopper is heavily charged with coal in a finely divided state. He had seen an ordinary large oil lamp lighted, and burning with a considerable flame, introduced several times into such a hopper without causing an explosion; hence some other condition or conditions seem to be necessary to cause an explosion when the air is merely charged with coal dust, and these would appear to be—

1.—The coal dust must be in a dry state; and, to have full effect, the surrounding air must be warm and dry.

2.—The flame, to ignite the coal dust, must have a high temperature. A case illustrating these conditions occurred, in 1860, in the county of Durham. Two men were working in a warm, dry atmosphere, heavily charged with fine coal dust, at a depth of not less than 250 fathoms from the surface, shooting down a balk or depression of stone which had thinned the coal-seam at the face of a working place. A hole was drilled in the stone and charged with powder. Both men had safety lamps (improved Stephenson), but one of the lamps had been unscrewed to light the fuse, and had been screwed on afterwards. The charge had gone off, but did not blow out much stone, so that it had acted nearly as a blown-out shot. For a distance of at least 80 yards back from the place where the shot was fired, the sides of the props and timber exposed to the force of the blast were found covered with charred coal dust to a depth varying from one-eighth to one-quarter of an inch. After lighting up the fuse, the men had retired to the first bord on the out-bye side, when their lamps were afterwards found perfect. After the explosion the men had endeavoured to make their way out, as one of them was found 40 yards, and the other 60 yards away, both having been suffocated by the after-damp, one of them being only very slightly burned. No gas had been found either before or after the explosion in the district, at any rate not in sufficient quantity to show upon the lamp, and no indication of a sudden blower of gas could be found.

It appears from the paper under discussion that coal dust will explode under another condition, namely, when it falls in bulk and comes in contact either with a flaming fire or the hot flame of a gas jet, as mentioned in Appendices 4 and 5. In trying some experiments which confirm this, he found that it is not absolutely necessary that the fire upon which it falls should be flaming, for if fine, dry coal dust in bulk be allowed to fall from a height on to a bright coke fire, a considerable explosion will take place. He would be glad if the authors of the paper could say whether they have tried any experiments to show what temperature is necessary to cause an explosion of coal dust, as it appears to be an important point in the inquiry. Is it not probable that, in coal dust explosions, the heat from the initial explosion causes the coal dust to evolve gas, which, being ignited, augments the explosion, and that without this initial heat to evolve the gas no explosion from coal dust can arise?

In conclusion, Mr. Logan stated that explosions were frequently known to take place when coke-ovens were re-charged from the top, shortly after having been drawn, with coal that had been finely pulverised by a

Carr's disintegrator, especially when the first tub emptied is more than usually fine, or, as it is called by the men, dusty or sooty. The flame from these explosions is sometimes projected as far as six feet outside the oven.

Mr. ROBERT STEVENSON said, he was sorry he had not brought with him any very definite information, as he had not intended to take any part in the discussion, but having mentioned the matter to the Secretary, that gentleman had requested him to state a few of the facts which he had met with in mining in North Staffordshire. The coals there are impregnated with hydro-carbon gas to a great extent. When the mine was dry, the ventilation good, and no gas present, when the miners were at work, sufficient dust was produced to show a cap on the flame in the safety-lamps, which cap was not produced after the men had ceased working for an hour or so and the dust had settled down or had passed away with the current of air; and as the ventilation and all the other circumstances connected with the place were in the same condition both when the men were working and when they had ceased, the inference was that it was the dust raised by their work and not gas that had produced the cap. He, himself, had often seen under similar circumstances a cap an inch in height over the flame in a Davy-lamp, accompanied by brilliant scintillations, which he considered plainly showed that the dust was explosive; indeed, they had had several explosions which could not be ascribed to anything except this coal dust. He considered the subject itself was one of very great importance, and had been very ably treated by the authors of the paper they were discussing, and he would be very glad if the Institute would carry these experiments still further, and find out some method of preventing the explosions which occur from coal dust. He thought, also, that it was quite reasonable to suppose that coal dust was explosive, for the molecules of coal floating in the air might be compared to little balloons charged with gas which only required heat to develop, and which, when mixed with air in suitable proportions, were sure under certain conditions to explode; and, in firing shots in some of their seams, they had to use many precautions or they would have very many such explosions. For instance, the fireman, before he fires the shot, is directed to moisten the atmosphere within twenty yards of where the shot is to be fired; no shot was allowed to be tamped with coal dust; and the powder used was selected with special care, for they found that there were certain kinds of powder which were more likely to flame or cause a blown-out shot than others, and, from experience, they preferred cubical powder or solid cartridges which did not flame to the same extent as

common powder. Irrespective of this, the proportions of the constituents of the powder formed an important consideration, because, unless the powder contained within itself the necessary elements to produce perfect combustion before coming to the atmosphere, flame was sure to be the result; for, if carbonic oxide was the result of the explosion, it would absorb oxygen when it came into the atmosphere and cause flame before it entered into the more stable state of carbonic acid gas.

Mr. NEWALL said, he saw that Professor Marreco in his paper had referred to explosions in flour mills in America. In the October number of the American journal of "Science and Art" there was a paper which contains a short description of several explosions there. It was exceedingly interesting, and bore very strongly upon the subject of the explosion of small particles of carbonaceous matter.

The following is a copy of the paper referred to:—

ART. XXXIV.—ON THE EXPLOSION OF THE FLOURING MILLS AT MINNEAPOLIS, MINNESOTA, MAY 2, 1878, AND THE CAUSES OF THE SAME.—BY S. F. PECKHAM.

As I was sitting at the tea-table on the evening of May 2, I was startled by a noise that sounded as if something as heavy as a barrel of flour had been tipped over on the floor above. A few seconds later the sound was repeated, and we all ran to the door, which commanded a full view of the falls and manufacturing portion of the city. An immense volume of black smoke enveloped the spot where the Washburn A Mill had stood, and a perpendicular column of smoke was projected into the air, above the elevator, at least four hundred feet. The Humboldt and Diamond Mills were directly behind the elevator from the place where I stood. A heavy wind was blowing from a point a little to the east of north, a direction from the Washburn A Mill toward the elevator and the other two mills. In less than two minutes from the time of the first explosion, the elevator, which was 108 feet high, was wrapped in flames from top to bottom. If the structure had been saturated in oil the flames could not have spread much more rapidly. In five minutes flame and smoke were pouring from every window in the Day and Rollins, Zenith and Galaxy Mills, which were between the Washburn A Mill and the river, producing a conflagration which, from ordinary causes, would not have gained such headway in two hours. Six flouring mills, the elevator, a machine shop, blacksmiths' shop, and planing mill, with a number of empty and loaded cars, were in flames in five minutes from the time fire was first observed by any one who survived the disaster.

From my own point of observation, which was about a mile distant, but two distinct explosions were heard; others nearer heard three, the first not as violent as the other two; while those nearer still heard, in addition, a sound which they described as a succession of sharp hisses, resembling the sound of burning gunpowder. Those observers to the windward, whose attention was arrested by the light produced, beyond the distance of half-a-mile, heard only one or two reports, or failed to hear any report at all. From all the testimony in reference to sound it appears that the blow upon the

air was not sufficiently sudden to produce a penetrating sound, but rather a dull, heavy blow, which was not communicated laterally to any great distance.

Burning wheat or flour was smelled for several minutes before the explosion, by persons in such a position that the wind would carry the odour to them. Smoke was also seen issuing from what was known as the exhaust flour-dust spout of the Washburn A Mill for several minutes preceding the explosion.

At the instant the explosion occurred, all observers agreed that the Washburn A Mill was brilliantly illuminated from basement to attic. The illumination was reflected from the water at and around the falls in such a manner as to remind one observer of the effect of a brilliant sunset. Another compared it to the reflection of sunlight from windows when the sun is near the horizon. Still another, who was crossing the lower bridge, had his attention called to what appeared to be a stream of fire, which, as he described it, issued from a basement window and went back again. Immediately thereafter each floor above the basement became brilliantly illuminated, the light appearing simultaneously at all the windows, only an appreciable interval of time intervening as the stories ignited one after the other. Then the windows burst out, the walls cracked between the windows and fell, and the roof was projected into the air, followed by an immense volume of smoke and flame, which ascended to an estimated height of from six to eight hundred feet. As the column of smoke was expanded and borne off upon the wind, brilliant flashes resembling lightning passed to and fro.

Two men, so near the Humboldt Mill that they were nearly buried by the falling rubbish, and on the opposite side from the Washburn A Mill, heard a loud report distinctly while the walls of the Humboldt Mill were still standing, and at the same time were knocked down. Immediately after they saw flames issuing from the basement windows of the Humboldt Mill, and, at the same instant, before they could regain their feet, they experienced a second shock and miraculously escaped being buried beneath the falling walls.

The enormous and sudden displacement of air which followed the explosion, and the tremendous force which was consequently exerted laterally, was shown in the condition of the round-house of the Chicago, Milwaukee, and St. Paul Railroad, and the broken windows in all directions. The round-house was a wooden structure about forty or fifty feet from the Diamond Mill. The sills were drawn out toward that mill until the building burst, letting a part of the roof fall in and leaving the sides standing at a sharp angle. Ordinary windows, and those of strong plate-glass on Washington Avenue, one-fourth of a mile distant, were projected into the street. Not only the glass but the sash went out bodily, particularly in the lower stories of the buildings. Persons on the river at the water's edge noticed a displacement of the water, producing a wave, estimated to be eighteen inches high, before they heard the report of the explosion.

Whole sheets of the corrugated iron with which the elevator was covered, measuring eight by two feet, but quite thin, were picked up on the east side of the river more than two miles distant, and pieces of six-inch flooring from two to ten feet long were carried to intermediate points.

An examination of the ruins of the several buildings showed that the walls of the Humboldt Mill lay upon those of the Diamond Mill, and those of the Diamond Mill upon those of the west end of the Washburn A Mill, showing that the buildings did not explode simultaneously but successively. The Washburn A Mill evidently exploded

first from fire originating within it, and the high wind prevailing at the time carried the flame into the adjoining mills to the south, and away from the mills next the river. There was enough burning middlings and flour thrown through the broken windows of the latter mills to set them on fire, but they did not explode. Some significance may attach to the fact that the three mills that exploded were all running with more or less open French middlings purifiers, while the three that did not explode had been shut down for several days. There is no question but that the French purifiers project a great deal more dust into the atmosphere of the mills than those that are enclosed, but I have no doubt that in any flouring mill sufficient dust accumulates upon beams and machinery to produce an explosive atmosphere, if from any cause this dust is scattered into the air and flame is communicated to the mixture while the dust is suspended.

There was less than a barrel each of lard oil, lubricating oil, and high-test kerosene in the Washburn A Mill at the time of the explosion.

There is absolutely no proof that any explosive material other than is produced in the manufacture of flour from wheat was in any one of the buildings destroyed, in the cars around them, or in the neighbourhood. The testimony of millwrights conclusively showed that fire produced by heated bearings is of such extremely rare occurrence in flouring mills as to practically exclude such a cause.* No suspicion of incendiarism has ever been expressed.

A slight fire, the effects of which were in nowise serious, occurred in the Washburn A Mill about three months before the explosion. It was discovered from the outside of the mill that smoke was issuing from a spout or conductor that discharged the air that was drawn through between the stones. The object for which the air is drawn through is to cool the stones and to carry off the vapour produced from the wheat by the rise of temperature due to friction. In this case the effects of fire were traced back from the outside of the building to one of the sets of stones on the north side of the mill used for grinding middlings. The effects of flame, however, did not extend beyond the blower which produced the exhaust. This led to the conclusion that the fire did not enter the dust-house, although the smoke must have passed through it. It is supposed that the fire was caused by friction between the stones, they having run dry from one of the causes that may produce dry stones.

In answer to enquiries made of several millers in the Minneapolis Mills, I found them uniformly of the opinion that the meal or flour as it left the stones had a temperature of about 100 degrees Fahrenheit, or less. A number of careful experiments, made with an ordinary chemical thermometer, showed that the wheat enters the stones from the dryers at a temperature of fully 100 degrees Fahrenheit, and that it leaves the stones at 120 to 130 degrees Fahrenheit; the temperature of the ground middlings as it left the stones averaged about 10 degrees higher.

It was also the concurrent testimony of millers and mill-owners that dry stones are of comparatively frequent occurrence, and that they are practically unavoidable. I am convinced that in the Washburn A Mill the frequency of danger from dry stones was considerably increased in consequence of the large number of stones in the mill, and especially from the fact that so few men were employed having the immediate oversight

* These gentlemen concurred in the statement that the spindle which carries the stone had been known to become welded into the socket in which it revolved, stopping the stone. When asked if the friction produced a welding heat, one replied, "No, nowhere near it." It must be an example of perfect contact, producing cohesion.

of the stones. Only two men were employed at the same time for the forty-two run of stone, a number inadequate for that supervision which so important a matter demands, as it is impossible, from the large space occupied by so many stones and the noise incident to their action, that even with the usual signals employed, dry stones should be detected as soon as they become a source of danger.

Obstruction of the feed from any one of a number of accidental causes will produce dry stones. The danger arises from the friction of the stones heating the last portion of the grist that remains between the stones to a temperature sufficient to char it, or convert it into a substance resembling tinder, which would readily ignite from a spark produced by the stones striking together. Another source of danger arises from nails or gravel passing between the stones with the grist, and increasing the friction, producing either a rise of temperature or a train of sparks; perhaps both.

I am aware that numerous instances of dry stones can be cited that have proved perfectly harmless. An instance is on record in which a run of stone ground each other all night with no other result than the complete removal of the grooves which gave the stones a cutting face. On the other hand, cases have occurred in which the grooves became filled with charred wheat of a dark brown colour, packed into them so solidly as to require a mill-pick for its removal. It requires no argument to show that this tinder, thus formed, would become ignited from a train of sparks that would inevitably follow contact of the stones as the grist became compacted or completely removed from between them. It was found by experiment* that masses of flour that had become heated and charred, ignited readily and smouldered, but were inflamed with considerable difficulty; but it should be borne in mind that a number of sets of stones are connected with a common spout or conductor, through which a strong current of air is being continually drawn, and which is filled with a dense cloud of very fine particles of starch (chiefly), heated to a maximum temperature of 140 degrees Fahrenheit. Experiment also proved that the proper mixture of flour-dust and air would not burn explosively, except when brought in contact with flame. White-hot wires and glowing charcoal only burned the particles in contact with them; but it was found that burning pellets of charred wheat and flour would ignite wood, which a strong draught of air readily fanned into a blaze. Under the conditions previously stated, with a draught of air passing through the dry stones strong enough to convey the pellets of smouldering tinder into the common wooden conductor, an explosion becomes possible.

It is urged that these conductors are damp from condensed moisture, and also that a large amount of moisture escapes from the wheat and is conveyed away by the current of air. This loss is no doubt correctly estimated at from five to six per cent. It is, however, chiefly during the first grinding of the raw wheat that this loss is experienced. The middlings is dryer, is ground at a higher temperature and is ground finer, producing more dust. The higher temperature renders the material more inflammable, and at the same time ensures a more complete solution of the vapour in the current of air. Moreover, the first fire in the Washburn A Mill was traced directly to a set of stones which ground nothing but middlings, and all that is known concerning the origin of the fire that produced the explosion confirms the supposition that that fire originated in a set of stones on the opposite side of the mill, which was one of six sets, all of which were used exclusively for grinding middlings, discharging into a common spout or conductor, which communicated directly with the dust-house, in which the dust settled to the

* Experiments made by Professor L. W. Peck before the coroner's jury.

amount of several hundred pounds a day. An explosion in this conductor, communicating flame to the dust-house, would scarcely fail to cause the successive explosions of the dust-house and the different storeys of the mill, the shock of the first explosion being sufficient to throw the dust of the mill into the air.

The opinion expressed by one of the witnesses at the inquest, "that stones are liable to run dry at any time by accident," and that "dry stones can hardly be avoided by any amount of foresight," appears to be generally entertained by millwrights, millers, and mill owners. Let it be granted that all experience shows that 99 per cent. of dry stones injures nothing but the stones themselves, the one per cent. of residue is burthened with fearful possibilities. If dry stones cannot be prevented in small mills where one miller has charge of perhaps six run of stone, the danger is more than proportionally increased in a mill where one man has charge of twenty run, both with reference to prevention and detection. The problem, therefore, for the consideration of parties immediately interested is, how to prevent or detect dry stones, particularly those used for grinding middlings. This practical problem appears to be fundamental, and one compared with which all others are without much importance. It is true that but few millers are without their experience of minor explosions, or flashes resulting from careless use of lanterns or open lights. Indeed, I have been profoundly impressed with the generally innocent reputation of flouring mills when considered in the light of the immense number of accidents well-known to millers and insurance companies; a number surprisingly large if confined to those occurring in the States of Minnesota and Wisconsin within a few years past. The remedy in such cases is so obvious that the most ordinary care and intelligence is sufficient.

Mr. NEWALL remarked, that the explosion appeared to have been a very serious one, and the description showed how complete was the destruction, as some parts of the mill were carried away a distance of two miles.

The CHAIRMAN said, that the subject was one of the most vital importance, and he hoped that it would be brought before the Royal Commission that had been appointed to examine into all matters affecting the safety of mines, but whether it would be advisable for the Institute to introduce the subject to their notice or not, would be a subject for discussion at the next meeting of the Council. The real and practical question, as was said by the author of the paper, appeared to be, will the heat evolved in the consumption of the gases from coal dust be sufficient to carry on the explosion, to keep the fire burning in fact, and spread it through a length of district in which the coal dust and air are present? This seemed to be an important element in the question, because upon it depended whether the explosion would be a local one or whether it would spread through the pits, which would, of course, be very much more serious. But no doubt the experience which would be afforded by continued experiments would show how far the first explosion was able to carry itself on, and so extend through more remote distances.

Mr. D. P. MORISON said, they certainly found in their experiments that the heat evolved by a large charge of powder carried the explosion very much further.

The CHAIRMAN said, that in all other respects he thought the paper so full that there was little left to discuss or question, and that they ought to pass a vote of thanks to the authors.

Mr. MORISON said, he thought that Mr. Logan would find that Professor Marreco, in his remarks upon the subject, most distinctly stated that the heat evolved by the combustion of the first particles of the dust ignites those succeeding, and that it was gradually carried onwards in that way, one set of particles passing it onward to another, and it seemed to be entirely a question of degree of initial heat as to how far that might be propagated.

The CHAIRMAN—Yes, that seems to be the question.

Mr. BUNNING said, he did not know whether, in the course of these experiments, they had by any means found out whether fine coal dust was likely to pervade the whole of the workings of a pit in the same way that gas would do, or whether it would not be most likely confined to comparatively small districts.

Mr. G. BAILES said, that there was no doubt that coal dust set in motion in the inclines and elsewhere, would be carried onward by the ventilating current, and would enter into the whole atmosphere of the pit. In that state they found it did not explode or they would have explosions almost every day. It seemed that the conditions for dust to explode were, that the dust should be suddenly propelled by a current upon a flame, so that it could be ignited, and that the heat should be instantaneously transmitted from particle to particle so as to make it a continuous flame; otherwise that a flame should, with very great force, be projected through an atmosphere containing dust. He thought these two conditions essential to transmit heat to the particles, so as to develop the gases. For instance, a quantity of dust was continually passing from the screens at bank, and (in the case where these screens are used for the coals from the Hutton seam, which were very dry and which were very rich in gas) coming in contact with the gas burners without producing any explosion. But if this same dust were precipitated from a height upon a fiery lamp with a good deal of flame, then the coal dust might be expected to blaze up and communicate the flame to the dust above. He thought these were the only conditions under which dust could be said to be ignited and, in a measure, to explode. He believed that dust itself would not explode unless acted upon by heat set rapidly in motion.

Mr. BUNNING asked, if there must not also be a certain proportion of dust with the air to render it explosive? because, in the case of fire-damp, if there was an excess of gas an explosive mixture was not made. It might possibly be the same with coal dust, and that this excess of dust prevented an explosion occurring in the hopper spoken of by Mr. Logan.

Mr. ROBERT STEVENSON said, his opinion about explosion from dust was, that when the shot was blown out, the force of the shot drives these particles so closely together that when they do kindle they explode. He did not himself think they would explode unless there was some force of that kind to commence with.

Mr. BUNNING asked Mr. Stevenson whether, in the course of his experience, he could recollect that an explosion had ever taken place from coal dust ignited by a safety-lamp?

Mr. ROBERT STEVENSON said, he had never in his experience been able to trace any explosion to coal dust ignited by a lamp; but there had been explosions which they could not trace to any other cause than coal dust.

Mr. BAILES said, he had often observed that in a mine where dust accumulates it hangs about the lamp, and that if the lamp were shaken it fell through the gauze and filled the lamp with flame. That showed that the heat in the lamp, or at least the heat generated by the dust coming in contact with the flame, is suddenly prolonged in the gauze, and that all the dust gets into a state of ignition. This he had repeatedly observed in some seams, and he should think that it was a matter which could become very dangerous in connection with the use of the safety-lamp in the presence of gas. He knew that in the old time it used to be a matter of very serious consideration to him to know what might happen in case any of the workmen might shake the dust so as to fill the lamp with flame when it indicated the presence of fire-damp.

The CHAIRMAN said, he supposed that the cap which Mr. Stevenson spoke of would not be the usual blue cap, it would be more of a brownish colour.

Mr. ROBERT STEVENSON—No; it was the usual colour, and scintillated, whilst small explosions were taking place inside the lamp at the same time.

Mr. W. J. BIRD stated, that some time ago, when watching the action of Rigg and Meiklejon's coal-cutting machine in the main coal seam at Elemore Colliery, he observed that there was a great quantity of fine coal dust going through the workings, which, when passing by the safety-lamps, caused the flame therein to scintillate considerably, but he did not observe that it produced any cap in the flame.

Mr. D. P. MORISON thought that it would be as well if members would kindly communicate the results of any experience they had had on this subject, either to the Secretary or to the authors of the paper, and that such communications should be embodied in the Transactions.

The CHAIRMAN said, that he thought Mr. Morison's suggestion a very valuable one, and that another paper on the subject, containing the varied experience of the different members, would prove a useful addition to their Transactions. They would now adjourn the discussion, and perhaps Professor Marreco and Mr. Morison would let them have, on another occasion, the results of some further experiments.

The following "Further Remarks on the Detection and Measurement of Small Quantities of Inflammable Gas," by Mr. E. H. LIVEING, A.R.S.M., were then read :—

FURTHER REMARKS ON THE DETECTION AND MEASUREMENT OF SMALL QUANTITIES OF INFLAMMABLE GAS.

By E. H. LIVEING, A.R.S.M.

Since describing in August last a new method of detecting very small quantities of inflammable gas and of estimating the proportion present, the writer has considerably modified the arrangement of the instrument then described, having found that far better results are obtained by the use of a different form of photometer.

The instrument is now in a much more practical form, and is capable of detecting and measuring gas without difficulty even when only one-fourth of a per cent. is present. It is represented in section in Plate XXXIV., and consists of a brass tube about eight inches long by one-and-three-fourth inches diameter, closed at the ends by discs of hard wood. Through these pass the insulated connection wires carrying the fine platinum spirals A and B, supported in the manner shown at H. The one (A) covered with a glass tube, the other exposed to the air within the instrument as before described. Between these spirals is supported a small wedge-shape screen C by means of an arm E. The two surfaces of this screen are covered with white paper, and are viewed through the small glass disc G in the side tube F, to which the arm and screen are attached.

One face of this little screen is illuminated by the covered wire A, the other by the working wire B; the wires themselves never being seen whilst the instrument is in use.

On turning the magneto-electrical machine the two surfaces of this screen appear equally illuminated; but if gas is present, that surface of the screen which is opposed to the working wire B appears brighter than the other.

Thus a particular pair of platinum spirals which were equal in illuminating power when no gas was present, when the instrument was

filled with air containing $\frac{1}{4}$ per cent. of gas, had a relative illuminating power of ... ... 1 to 1·24.

With $\frac{1}{2}$	per cent.	...	...	...	...	1 to 1·65.
1	do.	...	...	...	...	1 to 2·78.
2	do.	...	...	...	...	1 to 5·1.
3	do.	...	...	...	...	1 to 22.
4	do.	...	...	...	...	1 to 64.

In order to measure this inequality of brightness it is necessary to slide the screen towards the covered wire until the two surfaces again appear equally illuminated, and the amount of this movement becomes a means of measuring the quantity present, an empyrical scale of percentages being graduated on the body of the instrument at M, and read by means of a small index attached to the outer tube K. Into this tube is screwed the side tube F, together with the arm and screen, a slot in the body of the instrument admitting of their travelling towards the covered wire, the slot itself being covered in all positions by the outer tube K.

Two Hemmings' jets (P P) admit of the air being drawn into the instrument for examination in the manner formerly described.

When moderately large quantities of gas, such as 2 or 3 per cent., are present, the difference in *colour* of the light emitted by the two wires becomes so striking as to cause some difficulty in judging of the exact position of equal illumination of the screen, when measuring the quantity of gas present, a difficulty of course felt more or less with all photometers in examining lights of different tint. This difficulty is avoided in the following manner:—One-half, Y, Fig. 4, (which shows an enlarged view of the screen C) of that side of the screen which is exposed to the working wire B is covered with yellowish red paper, the other half, X, being left white. For quantities up to 1 per cent. the white surface X is compared with the white surface Z opposite the covered wire A, and in quantities greater than one per cent., the yellow surface Y is employed, as its tint, neutralises the very white light emitted by the working wire, and renders the comparison easy.

The instrument is so constructed that the platinum wires can easily be replaced in case of accidental melting or other damage, by having duplicate wooden plugs L with the standard wires ready attached and tested by the instrument maker, and all that is required is to unscrew the plate M and remove the old plug and replace it by a new one; then after making the proper connections with the conducting wires, and replacing the plate M, the instrument is again ready for use. Not that there is any excuse for melting the wires, as with ordinary care there is not the

smallest danger; the writer has a pair which have been in use some months, during which time they were subjected to a great number of experiments, and are still quite uninjured.

The writer would suggest that the instrument is more especially adapted for the examination of the various returns from the districts of a colliery, for it will show whether the total amount of air allowed to any particular part of a mine is ample for the gas there evolved, and enable the air to be regulated in the various splits in the most economical manner. Again, if a regular account of the percentages found in the various returns be kept, together with the quantities of air passing, barometric pressure, &c., it will soon become evident within what limits the proportion of gas usually varies; and if subsequently at any time a sudden abnormal increase in any particular district were to occur, even though still far below the explosive point, it would be desirable to follow the return up until the source was ascertained, and then, if necessary, take suitable precautions.

It has appeared to the writer undesirable to lengthen these brief remarks by entering into a full account of a long series of experiments made to determine the most favourable arrangement of the platinum wires, as to their size and the proportion of the spiral in which they should be formed to give the maximum effect, or of those again which have been made on many hundreds of mixtures of pit gas, pure CH_4, hydrogen, and coal gas with air, to ascertain the difference of brilliancy observable with the selected arrangement of wires when exposed to air containing various proportions of the above gases; suffice it to say that the success of the instrument to a great extent depends on the proper arrangement and careful adjustment of the platinum spirals, and that the scale obtained with various samples of pit gas (collected over water from blowers) closely resembles that obtained with pure CH_4, the pit gas having as a rule a slightly feebler action, probably from dilution with a small proportion of nitrogen or carbonic acid.

Carbonic acid appears to have no action on the instrument except to the extent to which it diminishes the heating power or combustibility of the gaseous mixture. Thus a mixture of 2 per cent. CH_4 and 2 per cent. CO_2 in air when examined in the instrument gave very nearly the same position on the scale as 2 per cent. of CH_4 alone.

In this respect, therefore, as well as in its extreme sensitiveness, this instrument possesses great advantages over any of a portable kind hitherto contrived; for, on examining the above mixture with Mr. Ansell's aneroid indicator (Vol. XV., page 165) it would have been recorded as

about 1 per cent. of CO_2, that gas more than counteracting the action of the CH_4 in the mixture. On the other hand, with his balloon instrument the mixture would have had a similar effect to about 4 per cent. of CH_4, since both gases acted in the same manner upon it. So also with Professor Forbes' instrument (described in a paper before the meeting of the British Association at Dublin, 1878); it would have been recorded as free from gas, since CO_2 almost exactly neutralises the effect of CH_4 on that instrument.

The instrument now described gives at once the heating power or approach to combustibility of the gaseous mixture examined, showing to what extent the percentage of CH_4 present must rise before the mixture will become capable of supporting or continuing its own combustion; in other words, will become explosive.

To illustrate Mr E.H. Livering's further remarks on the detection & measurement of small quantities of inflammable Gas.

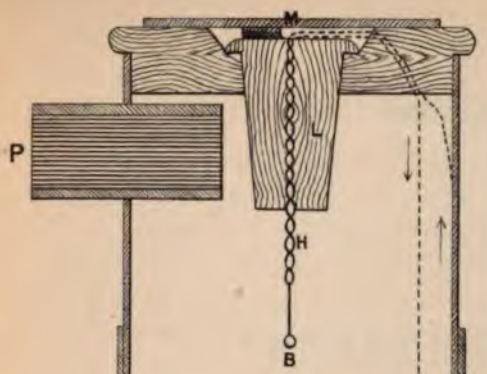


FIG. 1.

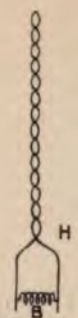
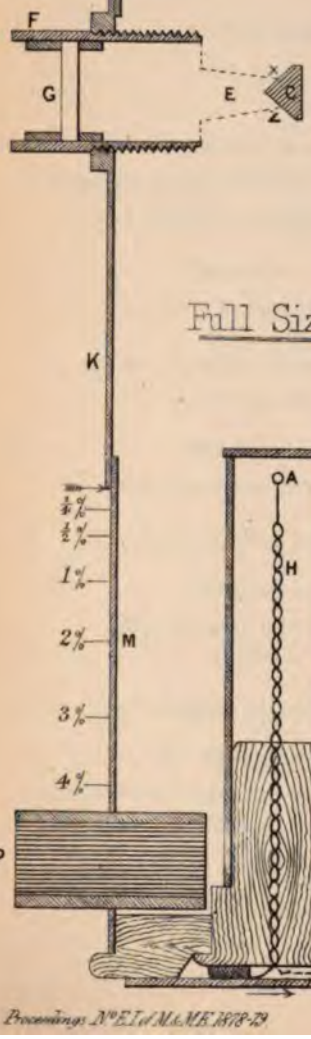


FIG. 2.

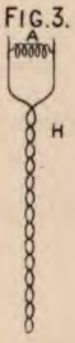
FIG. 4.

Enlarged View of the Screen C & Side Tube E



Full Size.

FIG. 3.



PROCEEDINGS.

GENERAL MEETING, SATURDAY, MARCH 1ST, 1879, IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE.

WILLIAM COCHRANE, ESQ., IN THE CHAIR.

The SECRETARY read the minutes of the last general meeting, and reported the proceedings of the Council.

The following gentlemen were then elected :—

ASSOCIATES—

Mr. JOHN ELYOTT DOYLE, B.A., Lecturer in Natural Science, St. Peter's Terrace, Birmingham.

Mr. PATRICK DOYLE, C.E., F.G.S., Superintendent of Public Works, Surveys, and Mines, Perak, *via* Penang, Straits Settlements.

STUDENT—

Mr. JAMES KENNETH GUTHRIE, Ryton-on-Tyne.

The following was nominated for election at the next meeting :—

STUDENT—

Mr. KENNETH MACKAE DAVIS, Towneley and Stella Collieries, Ryton-on-Tyne.

The following papers were then read :—

"On the Supply of Pure Water and Motive Power to Centres of Population," by Mr. David Burns.

"On Schmitt's Revolving Spiral Screen," by Mr. D. P. Morison.

ON THE SUPPLY OF PURE WATER AND MOTIVE POWER TO CENTRES OF POPULATION.

By DAVID BURNS.

This is a subject which commands the attention and affects the interests of all classes; and it is the purpose of the writer in the present paper to bring before the Institute, in outline, a scheme whereby the supply of water could be greatly improved, and the consumption of coal, with its concomitant evils, as smoke, explosions, and fires, be considerably lessened in many large towns.

For instance, there issues, near the crest of Cross Fell, a spring called the Gentleman's Well, which yields on an average all the year round over 50 gallons a minute of the most excellent water. It issues at an elevation of about 2,750 feet above the sea level; and if its water was conducted into a pipe so large as to lose no perceptible head from fluid friction, and carried down to Newcastle, it would supply 2,400 people with 30 gallons a day each, and give out a motive power of 39·4 horses at an elevation of 150 feet above the level of the sea.

It will be seen from this simple illustration what an immense store of motive power is allowed to run waste, and it requires no argument to show that to lead the Gentleman's Well down to Newcastle in a pipe, and so supply it in its original purity, is more philosophical than to allow it to spend its energy running down the valley of the Tyne, picking up sewage here and dilute manure there, and then to pump it up at great expense to supply the inhabitants of Newcastle with but indifferent drinking water.

The evil of taking water from rivers for household purposes is not likely to decrease in the future, whatever legislation may do to prevent their pollution: for the increase of population, and the greater intensity to which high farming will be carried on the low lands, and the greater height to which it will be pushed on the moorlands, will send an ever-increasing supply of soluble nitrogenous matter into them which it will be extremely difficult, if not impossible, to arrest.

The scheme the writer submits is, to collect all the available springs within the watershed under consideration at their outflow, so as to keep them pure and to make available the potential energy of their waters due to their respective heights, which energy might easily be supplemented by using windmills at convenient points and water wheels on the various streams.

Take a drainage area or valley with a river running down it, sundry tributaries running down on the right and left into the river, and springs of good water coming out at various elevations on the hill sides, with a town low down in the valley requiring pure water and power to drive its varied machinery, as a description of the locality of many large towns. At some convenient place well up the valley, and the higher the better, the writer would place a reservoir, which, for distinction, may be called the pressure reservoir. This should be connected with the town to be supplied by a large and strong pipe, which may be called the pressure main.

At each spring which it had been determined to make available, a reservoir should be formed, which may be called a spring reservoir. As springs often occur in clusters, one reservoir might serve for several, but each spring should be carefully led into it by means of a closed pipe. Each spring reservoir should be connected with the pressure main by means of a pressure pipe. In those cases in which the spring reservoir was as high as the pressure reservoir, the water would evidently flow from it of its own accord into the pressure main. When, however, the spring reservoir was the lower, the water would require to be forced into the pressure main. In such cases a force pump should be placed at the most convenient point for getting power on the line of the pressure pipe leading from the spring reservoir to the pressure main. If near a stream the pump might be driven by means of a water wheel or turbine turned by the water of the stream.

In those situations where water power could not be had, windmills should be erected of sufficient average power to do the work required. By such an arrangement any spring in the valley could be made available, and even feeders of water from the workings of a mine might become a source of water supply.

By the present system all sources below the level of the head reservoir are lost.

On reaching the town to be supplied, branches from the pressure main should be conducted through those thoroughfares in which are situated works requiring mechanical power. At each of those works should be a

hydraulic engine communicating with the pressure pipe of the street in which it is situated. The water having passed through the hydraulic engine should be made to deliver its water into another system of pipes, namely, the service pipes of the town. These would ramify as such pipes usually do, and would communicate with a service reservoir placed in some convenient position near the town, and at the lowest elevation consistent with giving a pressure sufficient to make the water circulate in the service pipes to the highest part of the town to be supplied.

PRESSURE RESERVOIR.

The best position for the pressure reservoir would depend much on circumstances. If the town required much motive power and little water in comparison, and the hills along the valley admitted of it, it should be placed at a considerable elevation. If, however, little power was required and much water, the pressure reservoir should be placed lower so as to command a greater quantity of water by gravitation. Its size would depend on many considerations, but mainly on the relation between the supply of spring water and the requirements of the town. If the supply of spring water was ample, the reservoir would only require to act as a regulator between the supply from the springs and the demand from the town; but when the spring supply was deficient it would require to catch and retain sufficient surface water to make good the deficiency.

The supply from the springs would be capable of regulation to a certain extent, and should be made as far as possible to supply water at the rate at which it was consumed in the town. Most of the consumption would take place during the working hours of the day, say from six a.m. to six p.m. Those springs above the level of the pressure reservoir could be easily turned on by an attendant during those hours, and turned off during the night. This arrangement would, however, not admit those springs supplied by the agency of natural forces, as wind and water power, without great loss. In periods of calm the windmills would be idle, and in extremes of drought and frost the water wheels would fall short in their duty. At such times the town would have to draw on the pressure reservoir and those springs above its level.

SPRING RESERVOIRS.

No water can be considered pure which is for any length of time kept stagnant in a reservoir and exposed to the impurities of the air, the action of the sun, and all other incidental sources of corruption. All the spring reservoirs should therefore be covered. This would be most effectually

done by driving galleries into the hill as near as possible on the line of the springs; by this means the spring would debouch into the gallery without the use of a pipe, and, in most cases, by driving on it for some distance, its flow would be much increased. When the gallery had been driven far enough to give the required capacity, the pressure pipe would be led into it, and its mouth built up, leaving a small hole for ventilation near the top. Such a reservoir would keep the water cool and pure, and it would be forced into the pressure main without coming to the day or receiving any impurities whatever. It will be noticed that the spring reservoirs would act as valuable auxiliaries to the pressure reservoir, especially those at or above its level; the others would do so in a limited degree, depending on the power which drove the force pumps.

To carry out this scheme in its entirety, the pressure reservoir should be a gallery like the spring reservoirs. Doubtless a gallery could be driven of any capacity, but one to hold water to supply a large town for several days would be very expensive. It might be well, therefore, to have a gallery of a moderate capacity to cover the ordinary daily fluctuations of demand and supply. At a little lower level, and communicating with the pressure main by a valve opening inwards, an open reservoir of the required dimensions could be formed to supplement the other supplies when necessary. By this arrangement the water of the open reservoir would only be drawn on at intervals and to a small extent. Thus, by proper engineering, water power could be had all the year round, and by placing the windmills in exposed situations they would never be long entirely idle.

It must be borne in mind in judging of a scheme like this that the storage required would be a mere fraction of that which is indispensable in the present system of catching the surface water of a district. At present but comparatively few springs can be made available, and a large proportion of the water is derived direct from the rainfall. From this cause storage has to be provided to meet the demands of the town and evaporation throughout several weeks of drought; but as all springs are more or less approximately constant, and many almost perfectly so even in prolonged periods of drought, all the storage required by this scheme is such as would meet the variation in the demand caused by any variation in pumping power. If these were either both constant or both varied alike little storage would be required.

PRESSURE PIPES.

The size of each of these pipes would depend on the quantity of water flowing from the spring in question. Their strength above the force pump

should be proportional to the depth below the spring reservoir, below the pump it should be proportional to the depth below the pressure reservoir. The line of these pipes need not be direct from the spring to the pressure main, but should be made to traverse that point where the power necessary to pump the water could be most cheaply and effectively obtained.

POWER.

The power necessary to drive any particular pump would be ascertained by multiplying the difference of elevation of the spring and pressure reservoirs by the weight of water yielded by the spring, and then again by a co-efficient for friction depending on the rate of flow of water in the pipe, its length and section and the number of bends The engine should be designed to be self-regulating as far as possible, and be driven by the most constant power available. In many cases it might be most advantageous to make the pressure main follow approximately the course of the river, and to drive the pumps by means of its water weired up at intervals.

PRESSURE MAIN.

As the loss of head in transmitting water through a pipe varies as the square of the velocity, it is evident that to have the pressure main large would be greatly to increase the power to be exerted in the town. The particular size selected would depend on the amount of power required and on considerations of first cost.

AVAILABLE POWER.

This would be the product of the weight of water flowing through the pressure main into the difference of head of the pressure and service reservoirs, less a deduction for friction and such like.

SERVICE RESERVOIR.

This need not be large and should be covered in. Under ordinary circumstances it need not hold more than a day's supply. It should be situated at as low a level as is consistent with a proper circulation through the service pipes so as to afford the greatest difference of head possible between the pressure and the service reservoirs.

It is no part of the writer's intention to bring forward a definite scheme for any particular district; still a few figures, by way of illustration, may be useful. For instance, if it is required to supply water to a locality requiring 7,000,000 gallons a day, a figure mentioned by Mr. Newall, in his paper read before this Institute on 3rd October, 1874,* as the quantity required for Newcastle and district. This quantity would be supplied by 162

* Volume XXIV., page 50.

springs, yielding on an average 30 gallons a minute. Now such springs, when a wide district is traversed, are not by any means rare, and many springs yield three and four times as much.

Having selected a suitable position well up on the hills where many springs come out, and where there is a good site for the supplementary open reservoir, let a gallery 8 feet high, 6 feet wide, and 200 fathoms long be driven. If this be driven along the strike of a water bearing stratum, or in the direction of the rise or dip of alternating beds, much more water is sure to be arrested than originally appeared in the springs. The gallery just described would have a capacity of 359,424 gallons. If 40 additional springs can be found at as high an elevation as the pressure reservoir, with an average yield of 30 gallons a minute, by driving a gallery 6 feet by 4 feet 100 yards on each of them, an additional storage of 1,797,120 gallons would be obtained, and their yield would probably be doubled, so that the half of the water required would be obtained and storage of 2,156,544 gallons provided independent of pumping.

Other springs, equivalent to 80 of 30 gallons each, would remain to be pumped. Probably 20 springs could be got which, if driven on a hundred yards, would provide the desired quantity of water; but suppose 30 galleries have to be driven of like capacity to the others, namely, 100 yards by 6 feet by 4 feet, this would provide 1,347,840 gallons more storage, or a total of 3,504,384 gallons. This is certainly not great storage, but it is equal to fully half-a-day's consumption, and would be equal to meet the fluctuations in the demand. The deficiencies in the pumping, if any, would require to be met by further galleries or by drawing on the open reservoir.

Let the effective head, that is the difference of level of the pressure and service reservoirs, less the loss of head due to friction and such like, be 500 feet. The energy would be thus calculated:—

$$7{,}000{,}000 \times 10 \times 500 = 35{,}000{,}000{,}000 \text{ foot lbs.}$$

$$\frac{35{,}000{,}000{,}000}{33{,}000 \times 60 \times 24} = 736{\cdot}5 \text{ horse power.}$$

Take the efficiency of the engines at ·7, and the horse power which can be actually applied to useful purposes is 515·5, working day and night, and all the year round.

By going up to Alston Moor or the Allendales for the pressure reservoir, there would be no engineering difficulty in getting twice this power from the 7,000,000 gallons of water a day. Such power could not fail to be a great boon to a community, and a source of considerable revenue to a corporation.

When the foregoing was put in form some months since, electricity as a means of transmitting force, and as a source of light had not attained the prominence it now enjoys. In view of the late achievements of science, and of the present demand for a better light, the scheme might be so far modified, and the water be made to drive a series of dynamo-electric machines, and the electricity could be conducted through the town to drive sewing machines, lathes, printing presses, and all such light machinery.

If electric lighting should become a permanent institution amongst us, a large proportion of the power might be used to light the principal thoroughfares, squares, halls, and workshops of the town.

Dr. C. W. Siemens, in his lecture delivered in the City Hall, Glasgow, on 14th March, 1878, states that one of his dynamo-machines, requiring 3·3 horse power, will produce a light equivalent to 4,138 candles. The light, therefore, which could be realised out of the force just given as available would be 646,406 candles. As the power is calculated on the understanding that the engines work continuously day and night, the above light could be supplied during the hours it was wanted, and the engine power of 515·5 horses would be available for the other purposes enumerated during the remainder of the 24 hours.

In submitting a scheme so radically different from those in use in supplying large towns, and which would be undoubtedly expensive, the writer would submit the following advantages which it possesses, and which he ventures to assert should not be lightly laid aside.

1.—The ground occupied by the present system of large reservoirs would be nearly entirely saved.

2.—The expense of making reservoirs and long water races would be largely avoided. This saving would go a long way towards making the underground reservoirs.

3.—The water available would not be left to evaporate in open reservoirs.

4.—The water would not be contaminated with peaty and soluble nitrogenous matter, nor exposed to the heat of the sun; indeed, pure spring water alone would be supplied to the town, and all filtration would be avoided.

5.—All pumping by steam would be avoided.

6.—By covering the service reservoirs the water might be effectively protected from the extremes of temperature. Cool spring water might be supplied in summer, and all disappointment and hardship avoided in protracted frosts.

7.—A large amount of power could be obtained sufficient in many cases to light the whole town during the hours of darkness, and do the work of many small steam engines during working hours.

The CHAIRMAN, in opening the discussion, stated that the paper contained matter deserving of much serious consideration, and that it was brought before them at a very opportune time after the difficulties in obtaining water that had been experienced lately in Newcastle. He thought the writer was too sanguine in his estimate of the amount of water to be obtained in the way proposed, and that the water when obtained, no matter how pure in its original state, would not be much better than that at present supplied to Newcastle after it had passed through the machinery he proposed it should drive. He also considered the use of wind and water mills objectionable, as steam would be found cheaper in the end.

Mr. J. A. G. ROSS stated that he considered the proposition, if not absolutely impracticable, would be very much more expensive than the direct application of steam power. The great drawback in the use of water as a motive power was the loss sustained from its inertia; and as this loss was the same at all pressures, it followed that the higher pressure used the more economical was the result. The distribution of power by means of hydraulic pressure has been successful in Hull, where a pressure of from 700 to 1,000 lbs. per inch was available, as well as in most of the docks and railway stations of the country; but even granting the utility of employing water pressure of a small head, he thought the mode proposed by Mr. Burn would be cumbersome and costly, and would necessitate a most unwieldy and complicated mass of piping to carry it out.

Mr. W. H. HEDLEY remarked that, for the daily consumption indicated of 7,000,000 gallons, he had roughly estimated the cost of making galleries to provide the amount of storage usually considered necessary at £2,000,000.

Mr. HENRY LAWRENCE thought that the expense of storing the water in galleries would be far more expensive than doing so in the ordinary reservoirs, even when these reservoirs were arched in, as at Lambeth and at Chelsea. The galleries would soon be full of impurities from falls in the roof and sides, and would be very difficult to cleanse; whereas the covered reservoirs were easy to get at, and the roofs could be kept properly white-washed and sweet. He considered the scheme impracticable.

Mr. BURNS considered that to some extent the objections to his proposal were founded on misapprehension, for it was manifestly unfair to compare the quantity of storage required by the ordinary plan, where the supply was obtained from the surface drainage and had to be sufficient to meet long periods of drought, and that required by his plan, where the supply was a continuous one. He thought that the galleries where insecure could be strengthened by brickwork, so as to prevent any inconvenience from falls; and the intrusion of noxious springs through the strata might be prevented by the same means, and he had the assurance of gentlemen well qualified to give a practical opinion that there would be no contamination of the water caused by passing it through properly constructed hydraulic machinery. There might be some extra first cost incurred, but this would be amply repaid by economy in the subsequent working of the scheme.

The CHAIRMAN then moved a vote of thanks to Mr. Burns, which was unanimously carried.

SCHMITT'S REVOLVING SPIRAL SCREEN.

By D. P. MORISON.

THIS screen has been introduced in the coal districts of Germany with great success. The chief advantages obtained by its use are:—

1st.—The cost is smaller than that of ordinary revolving screens, and the space occupied in proportion to the work done is very much less.

2nd.—The coal is not broken in the process of screening nearly so much as in ordinary revolving screens, while the screening into the required sizes is most efficiently done.

3rd.—The construction is simple and strong; all parts readily accessible and easily repaired.

4th.—The power required to drive it is less than with ordinary revolving screens, as the material being screened is more distributed, and does not all lie at the bottom of the screen.

The writer has been indebted to Mr. T. J. Danson for the following information, as well as the model and the diagrams illustrating the invention.

The development of the spiral screen shewn in Plates XXXV., XXXVI., and XXXVII. is simply a long strip of plate perforated throughout its length with holes of different sizes according to the sizes into which the coal is required to be separated. This strip would be about 54 feet long and 4 feet wide, and being wound into a spiral, and the ends closed and mounted on a central axle, it forms the spiral screen.

Plate XXXV. represents a section through the axis of a spiral screen, Plate XXXVI. a cross section, and Plate XXXVII. an end elevation. A is the axle or shaft on which the screen is mounted, and with which it revolves; BB are carriages (in which the bearings of the axle work) carried upon the frames CC at each end; D is the driving sheave round which a belt passes from the engine shaft; E is the elevator lifting the coals to the inclined spout

F, which conveys them into the central portion of the screen 1, which is a cone shaped circle, being larger in diameter at its outer end to facilitate the delivery of the larger pieces of coal which will not pass through the first series of holes. The whole of the other coal (passing through these holes) falls into the second division of the screen 2, and by the revolution of the screen is separated; the pieces too large to pass through the second series of holes being retained upon the plate until that point comes round where a channel 2A (Plate XXXVI.) receives them, down which they are discharged out at the side of the screen into depots or by spouts into wagons. The coals which have passed through the second series of holes in the division 2 fall into the third division 3, and as the screen revolves they are further separated, the pieces which will not pass through the third series of holes being retained until the channel 3A comes round, down which they run and are discharged by spouts into wagons as before. The smallest coal and "duff" has during this time passed through the holes in division 3, and is delivered out of the whole of the bottom portion of the screen into a hopper leading by a spout to the wagon. The unperforated or blank plates shewn by the full dark lines are to prevent the coal from being returned after passing through the holes, as the delivery through the side channels 2A and 3A takes place partially at or above the horizontal centre line of the screen, and not entirely out of the lowest segment of the circle as in ordinary drum screens.

The perforated plates forming the screen are put on in segments, and, when required, can easily be removed or replaced with plates having larger or smaller holes by taking out a few bolts.

A model specially made to represent a screen for screening coal into three sizes, and exactly one-fifth of the diameter and length of an actual screen capable of separating 400 tons of coal in ten hours was exhibited when the paper was read. The actual screen would be 8 feet diameter and 4 feet long. In the model, in order, as far as possible, to adhere to the relative proportions, the first perforated plate was a coned circle with a surface of 1·3 square feet, and holes $\frac{5}{8}$ inch diameter. The second plate was a portion of a spiral with a surface of 2·6 square feet, and holes nearly $\frac{3}{8}$ inch diameter; and the third plate was a continuation of the spiral with a surface of 3 square feet, and holes rather less than $\frac{1}{4}$ inch diameter.

The extent of surfaces and the sizes of the holes in an actual screen will depend upon the nature and composition of the coal to be screened and the sizes into which it is to be separated.

The coal in the model was introduced into the screen by means of a "hopper," with a worm screw or "creeper" working in it, but generally

and preferably with a view of avoiding unnecessary breakage, the coal is delivered direct from elevator buckets by a spout, as shown in the Plates.

The speed of an actual screen to deliver 400 tons of coal in ten hours is from ten to twelve revolutions per minute, but in dealing with very soft or tender coal Mr. Schmitt prefers a slower speed, and suggests that two spiral screens (each equal to treating three-fourths of the quantity) be used, and the speed reduced to six or eight revolutions per minute, the same elevators supplying the two screens.

The following table shows the comparative results obtained on the Rühr from actual working of ordinary revolving drum screens and of the spiral screen. In each case the bulk of the coal as worked from the pit is composed as follows, viz.:—

10	per cent.	pieces larger than	3	inch cubes.
11	do.	do.	$1\frac{5}{8}$	do.
12	do.	do.	1	do.
13	do.	do.	$\frac{1}{2}$	do.
10	do.	do.	$\frac{3}{16}$	do.
22	do.	do.	$\frac{5}{32}$	do.
22	do.	less than $\frac{1}{5}$ inch and duff.		
100				

This coal, as coming from the pit, is passed over an ordinary inclined screen, which takes off the blocks, or 20 per cent. of the whole, the remaining 80 per cent. being delivered by the elevators into the screens, by which it is separated into five sizes.

The arrangement and dimensions of the comparative screens from which the following table is compiled are shown in Plate XXXVIII., Fig. 1 being the revolving drum screen and Fig. 2 the spiral screen.

TABLE OF COMPARATIVE RESULTS.—ORDINARY DRUM SCREENS.
PLATE XXXVIII., FIG. 1.

First portion, 5 ft. 3 in. diameter, 15 ft. 9 in. long, 12 revolutions per minute.
Second do. 4 ft. 6 in. do. 14 ft. 9 in. do. 15 do. do.

No. of Section of Screen.	Diameter of Holes in inches.	Square feet traversed by the Coal per minute.	Coal delivered per minute.	Coal delivered per square foot per minute.
1	$\frac{3}{16}$	2,060		
2	$\frac{3}{8}$	1,030		
3	$\frac{1}{2}$	880	lbs. 1,490	lbs. ·252
4	$\frac{3}{4}$	1,000		
5	$1\frac{1}{2}$	900		
		5,870		
SPIRAL SCREEN. PLATE XXXVIII., FIG. 2. Internal diameter 2 ft. 9 in., external diameter 7 ft., length 4 ft. 3 in., 10 revolutions.				
1	$1\frac{1}{2}$	430		
2	$\frac{3}{4}$	490		
3	$\frac{1}{2}$	540	lbs. 1,490	lbs. ·520
4	$\frac{3}{8}$	650		
5	$\frac{3}{16}$	760		
		2,870		

From this table of results it appears that the ordinary revolving drum screen delivered 1,490 lbs. of coal per minute after passing it over 5,870 square feet of surface; and that the spiral screen delivered the same quantity, but passed it over a surface of only 2,870 square feet, or with fifty per cent. less surface traversed. By the table the spiral screen delivers the same quantity of screened coal as the revolving drum screens, the coal in each case being separated into five sizes, exclusive of the larger pieces which will not pass through the largest holes in the screens, but this degree of separation not being required in England, the process of screening can be simplified in proportion. The circumferential speeds of the screens are, in the case of the first portion of the drum screen, 198 feet per minute; in the second, 210 feet per minute; and in the spiral screen, 150 feet per minute at the mean diameter.

The greater quantity of coal screened on a given surface by the spiral screen may be accounted for by the fact that the coals lie in thinner

layers (being more distributed), and that they move on a horizontal plane, while in the drum screens they have, besides the revolving motion, a lateral sliding motion down the incline of the drum. Then, in the drum screens, the "duff" has to find its way through the smallest holes in the first section of the screen, the "peas" through the next, and so on. Thus, the larger pieces of coal remain on the screen till the whole process of separation is completed; while in the spiral screen this is exactly reversed, as the larger pieces are first separated and thrown out, the "nuts" next, then "peas" and smaller sizes, and finally the "duff." It is therefore certain that the "duff" must be perfectly separated from the other sizes, which are also each better defined than by the drum screens.

Another important point is gained by the larger pieces being first disposed of, viz., that they are thus prevented from being knocked about among the smaller sizes to the breaking up of both. The absence of this knocking about, coupled with the fact that a given quantity of coal while being screened has in the spiral screen to pass over only half the surface required in the drum screens, fully accounts for the great difference in the amount of breakage of the coal in the two kinds of screens, because the breakage increases exactly in proportion to the surface traversed by the coal in the process of screening. Hence, it is less in the spiral than in the drum screen by 50 per cent. on this ground only. Further, the breakage caused by the larger pieces being retained on the screen increases as the cube of the size of the pieces (the weight of which is as the cube) and, by calculation made upon this data, it is found that the breakage while in the screen is less in the spiral by 90 per cent. This so far is theoretical, but based upon correct principles, and, to a great extent, confirmed by actual results. However, the mere saving in breakage by the smaller extent of surface traversed by the coal in the spiral screen is in itself a valuable result, and it is a practical fact according to the testimony given by managers of coal mines in Germany.

The mode of dealing with the coal in Germany is described as follows:— The rough coal as it comes from the pit is passed over an ordinary inclined bar screen which retains the larger coal, and delivers it at the bottom on to a travelling belt upon which it is cleaned, the stones, slates, &c., being taken out. At the end of the belt it falls into wagons and is taken to market. The small coal, which has fallen through the bars of the screen into a pit, is taken by an elevator up to the spiral screen, whence the sizes above "duff" are delivered into pulsating washing machines. The coal floating off the surface is passed over strainers, to take off the water, and then runs down into depots, and is also taken to market,

the refuse slate, pyrites, &c., being carried away by creepers into tubs. The smaller coal next to "duff" is taken into a disintegrator and crushed for coking, and the "duff" (which has not been washed) is also crushed and made into coke.

The principle has also been successfully adapted for sorting ores into various sizes, but its application to coal has alone been dealt with in this short notice.

In conclusion, the writer would draw attention to the manifest advantage which would result by eliminating from the "duff" such marketable coal as "peas," or "small" without dust.

The CHAIRMAN, after inviting discussion, stated that if the benefits which Mr. Morison claimed for the screen were carried out in practice, there was no doubt it would be a great improvement upon the ordinary revolving screen, although if it was necessary in the first instance to separate the large coal by an ordinary inclined screen, this additional plant would be required, and the breakage incident to that process would still take place.

Mr. MORISON stated that the screen was constructed to separate the duff and the different classes of small, and that when the ordinary inclined screen was used to separate the large pieces, the present inclination of such screens could be considerably reduced with a proportionate saving of breakage.

The CHAIRMAN said, they were very much obliged to Mr. Morison for bringing practical machinery of this description before them, the use of which would save labour and improve the quality of the work. He had much pleasure in proposing a vote of thanks to that gentleman, which was unanimously responded to.

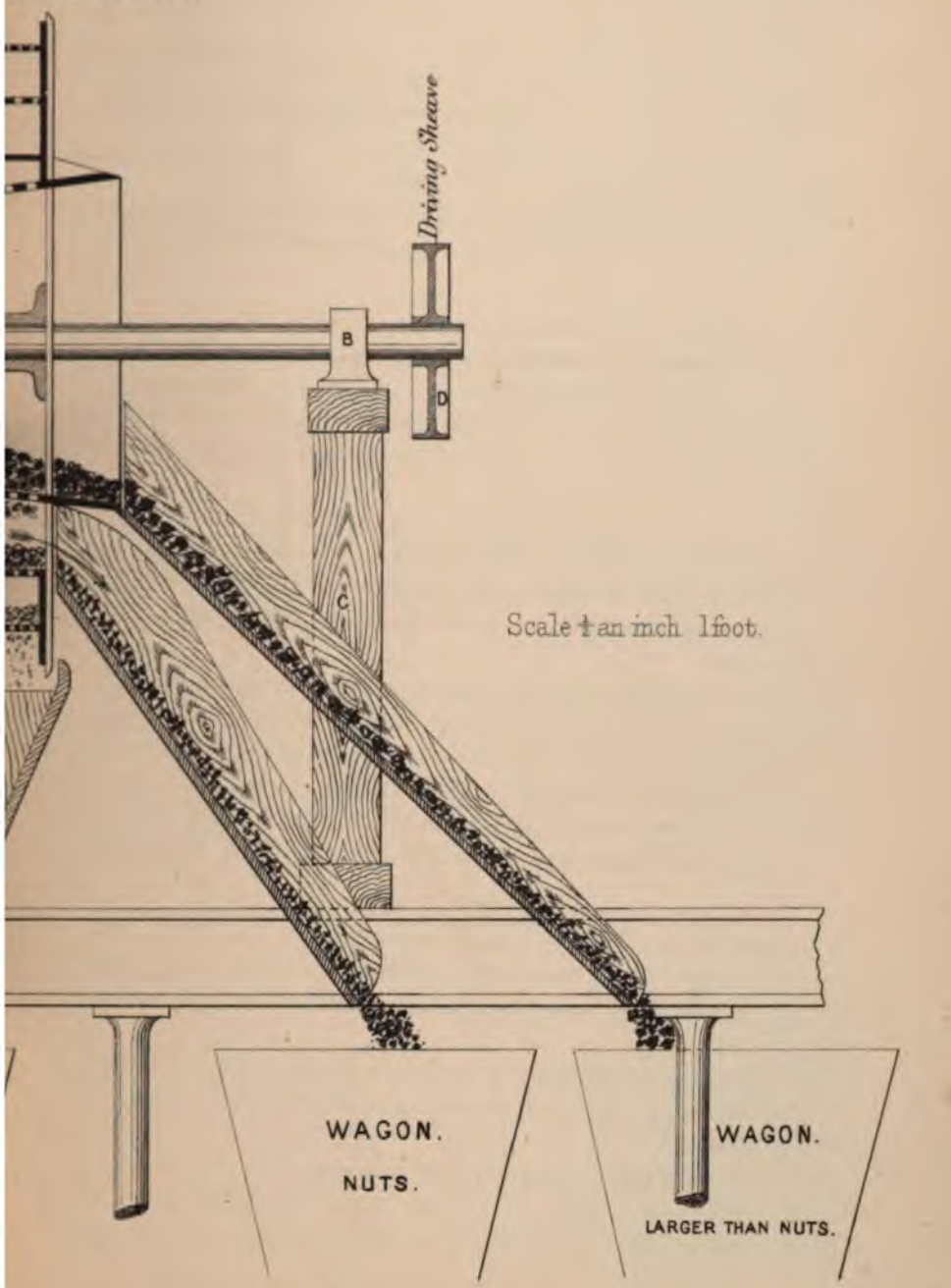
The CHAIRMAN then announced that Mr. Morison's paper "On Rigg and Meiklejon's Coal-cutting Machine" was open for discussion, and asked if Mr. Morison had anything more to say upon the subject?

Mr. D. P. MORISON stated that since the paper had been read he had made a point of going to Scotland and making himself personally acquainted with the working of the machine at Penston Colliery, near Tranent, where the owners had had two years' experience of its efficiency, and he did this because he desired that the members of the Institute should be in possession of the most reliable information on the subject. He was bound to admit that after his inspection his opinion on the value

Revolving Spiral Screen.

EEN.

LATE XXXVI.

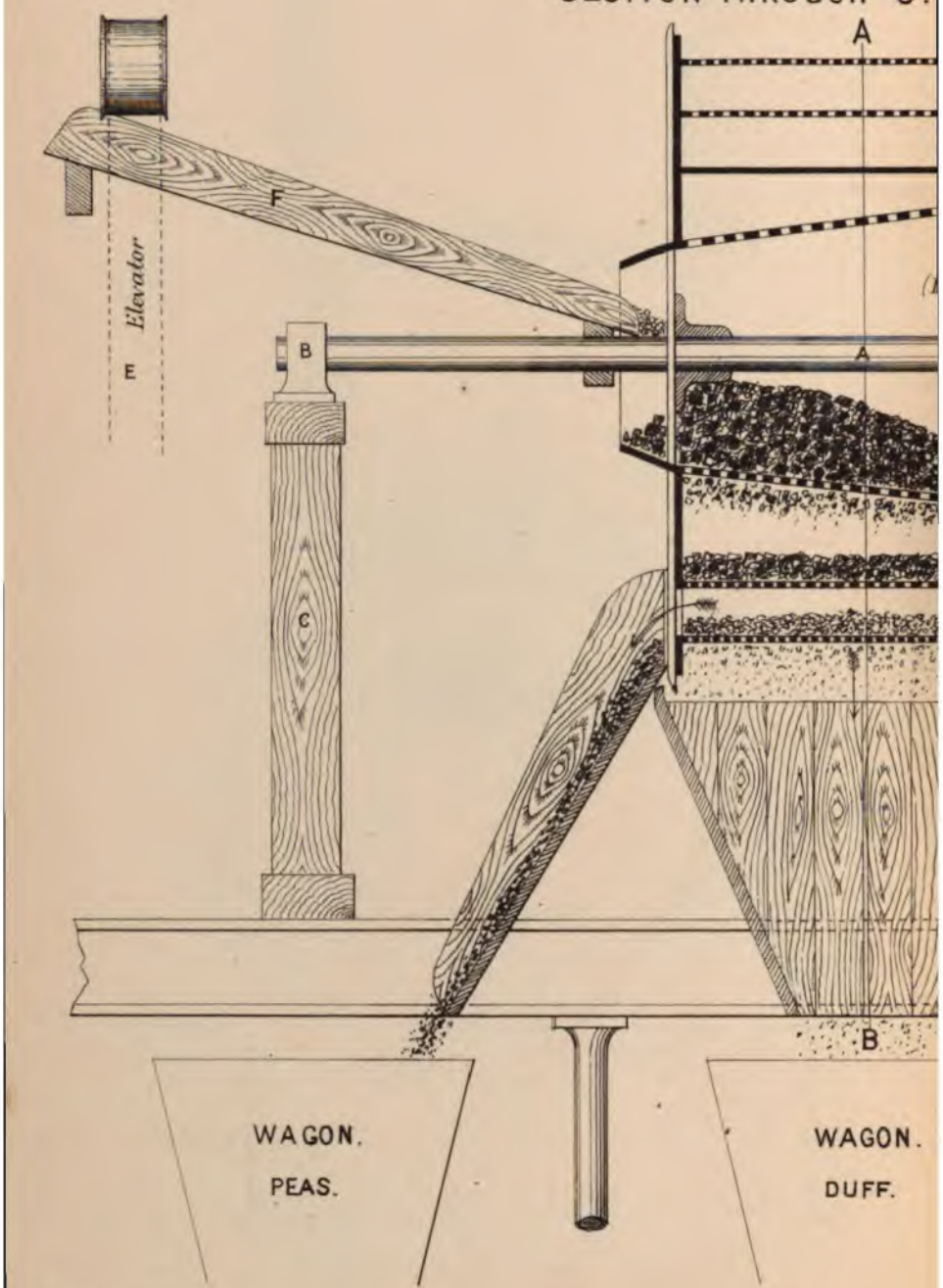


To illustrate M.r D. P. Morison's paper "On Sci

SPIRAL COAL S

(Schmitt's Pate

SECTION THROUGH C.



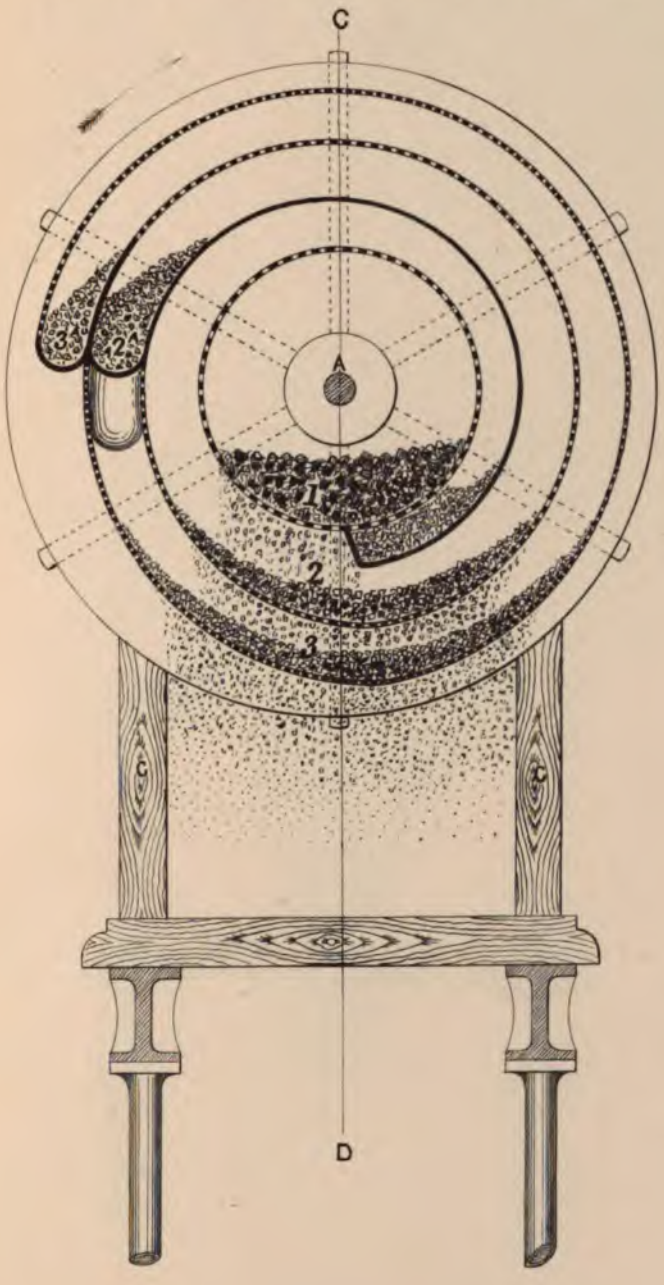
Proceedings N.o E.I. of M.& M.E. 1878-79.

To illustrate M.r D.P. Morison's paper "On Schmitt's Revolving Spiral Screens."

SPIRAL COAL SCREEN.

(Schmitt's Patent.)

SECTION THROUGH A.B. PLATE XXXV.



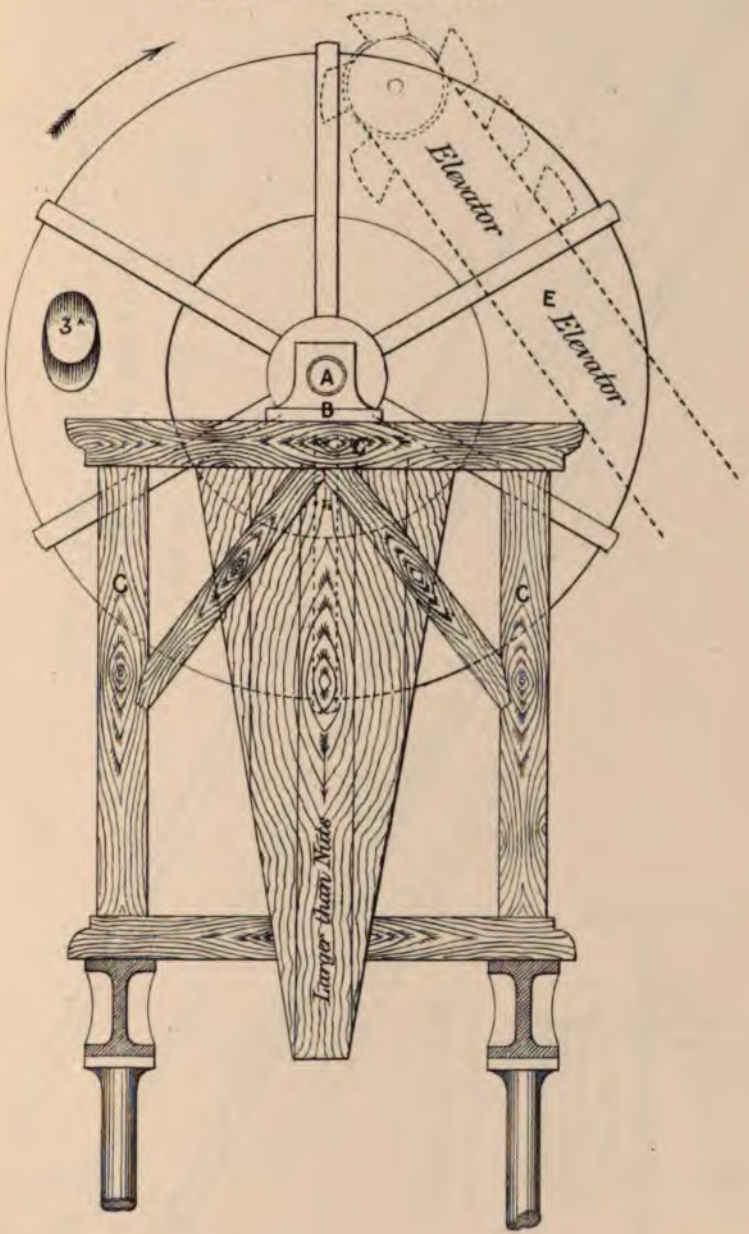
Scale ½ an inch - 1 foot.

To illustrate M^r D.P. Morison's paper "On Schmitts Revolving Spiral Screens."

SPIRAL COAL SCREEN.

(Schmitt's Patent.)

END ELEVATION.



Scale $\frac{1}{2}$ an inch = 1 foot.

To illustrate M.r D. P. Morison's paper "On Schmitt's Revolving Spiral Screen"

REVOLVING DRUM SCREENS,
AS USED ON THE RÜHR,
To Screen 400 Tons in 10 Hours.

FIG. 1.

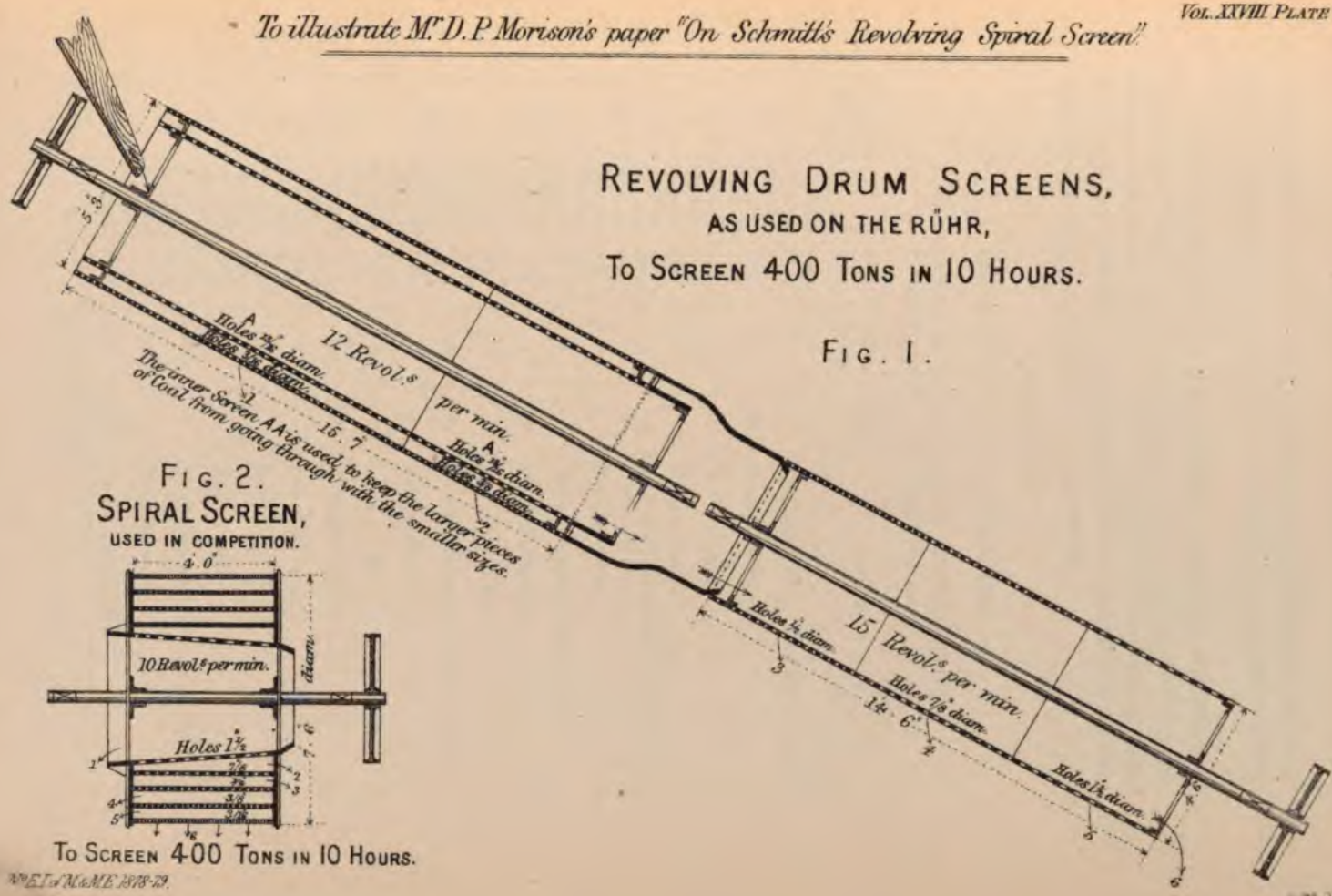

A
Holes 2½ diam.
12 Revol.s per min.
15. 7
The inner Screen A A is used to keep the larger pieces of Coal from going through with the smaller sizes.
A
Holes 1½ diam.
Holes 1¼ diam.
Holes 1 diam.
Holes ¾ diam.
Holes ½ diam.
15 Revol.s per min.
Holes ⅞ diam.
Holes 1¼ diam.

FIG. 2.
SPIRAL SCREEN,
USED IN COMPETITION.

To Screen 400 Tons in 10 Hours.

M.E.I. of M. & M.E. 1878-79.

of the machine, and the figures representing its efficiency, had been modified considerably, in a way that, in his opinion, very much enhanced the value of the machine.

By the courtesy of Messrs. Deans and Moore, the owners of the Penston Colliery, the writer descended the pit on the afternoon of the 4th February, in time to see the machine start work on the long-wall face of coal prepared for it; and the following is a transcript of the notes made on that occasion from the start until the end of the face was reached.

TABLE No. I.

PENSTON COLLIERY, 4TH FEBRUARY, 1879.

WORK PERFORMED BY RIGG AND MEIKLEJON'S COAL CUTTER, WORKING WITH 35 LBS. PRESSURE OF AIR.

STOPPAGE. Minutes.		TIME. h.m.	CUTTING. Minutes.	TOTAL YARDS CUT.	CAUSE OF STOPPAGE.
	Started.	3·30			
	Stopped	4·10	40	24	To change cutters; 8 cutters changed.
20	Started.	4·30			
	Stopped	4·45	15	38	Small fault in coal.
3	Started.	4·48			
	Stopped	5· 5	17	... ...	To change rails.
5	Started.	5·10			
	Stopped	5·12	2	... ...	Sleepers slipped.
9	Started.	5·21			
	Stopped	5·25	4	54	To lengthen chain and to change cutters—all blunt.
20	Started.	5·45			
	Stopped	5·47	2	... ...	One cutter bent.
5	Started.	5·52			
	Stopped	6· 3	11	... ...	To change rails and alter level.
6	Started.	6· 9			
	Stopped	6·12	3	64	One cutter lost off.
7	Started.	6·19			
	Stopped	6·38	19	... ...	Disc catching floor.
2	Started.	6·40			
	Stopped	7· 2	22	89	To change cutters and "bait" time.
30	Started.	7·32			
	Stopped	7·42	10	... ...	Sleeper slipped.
3	Started.	7·45			
	Stopped	7·48	3	... ...	Do. do.
3	Started.	7·51			
	Stopped	8· 1	10	102	To lengthen chain.
9	Started.	8·10			
	Stopped	8·14	4	... ...	One cutter loose.
3	Started.	8·17			
	Stopped	8·18	1	... ...	Same do.
9	Started.	8·27			
	Stopped	8·30	3	... ...	Same do.
10	Started.	8·40			
	Stopped	8·46	6	... ...	To change 6 badly-tempered cutters.
17	Started.	9· 3			
	Stopped	9· 5	2	... ...	To change rails.
5	Started.	9·30			
20	Stopped	10· 5	35	129½	End of prepared face.
186 mins.	TOTAL		209 mins.	129½	

	Hrs.	Mins.
Stoppages	3	6
Cutting	3	29
TOTAL TIME	6	35

Or 129½ yards per shift of 6 hours 35 minutes.
„ 19·68 yards per hour of shift.
„ 37 yards per hour of cutting.

Stoppages beyond control of machine:—

	Minutes.
"Bait" time	30
Badly-tempered tools	24
Small fault	3
	57
Regular stoppages, changing rails, cutters, etc. ...	129
TOTAL STOPPAGES	186

The length of wall prepared before each night shift for the machine may be taken as 130 yards, although in some cases 150 or 170 yards have been cut during the duration of the shift, from six-and-a-half to eight hours at the face. The whole of the work is performed by three men and one boy, who are paid by the ton, and is filled the next shift by the fillers. The average depth of cut was, on the night in question, slightly over 3 feet 2 inches, but the writer is assured that 3 feet 5 inches may safely be taken as the average. The height of the cutting (or kirving) is very regular, not exceeding 3¼ inches at the front.

The prices paid for the machine work may be estimated at:—

	s.	d.	
Coal cutting, labour as above		3	per ton.
Maintenance of machine, repairing and tempering cutters, lubricants, etc.		1	„
Fillers (round), 4d. per tub (20 to score, 6 cwts. each); Chews, 3½d. per tub; dross, 2d. per tub, say ...		11	„
	1	3	„
Add as per Table No. II. for interest on plant at a maximum		3½	
	1	6½	
Cost of hewing		7½	
Cost of filling		11	
	1	6½	

This cost is stated by Messrs. Deans and Moore to be less than half the cost of hand-work in other parts of the pit where the coal is higher. Hand hewing could only be introduced at very great expense in the

district where the cutter is at work, on account of the average thickness of seam being so small, and would result in a loss of more than 50 per cent. of the round coal obtained by the machine.

The approximate comparison of round coal per ton cut by the machine at Penston may be assumed to be on the average:—Round, 12 cwts. per ton; chews, 3 cwts. per ton; duff, 5 cwts. per ton. By hand holing they would not obtain more than 9 cwts. per ton of round, even where hand holing was practicable, and in this district probably only 6 cwts. per ton would be produced.

The writer would wish to correct the figures given to him for his paper, they having been somewhat overstated. The following table will be found a correct estimate of the plant required, and of the actual cost per ton taken over the past twelve months:—

TABLE No. II.

COST OF PLANT REQUIRED FOR THE WORKING OF ONE OF RIGG AND MEIKLEJON'S PATENT COAL-CUTTING MACHINES.

One steam boiler, with fittings complete	£300
One air-compressing engine, with steam engine combined ...	520
One air receiver, or old boiler	30
One machine, with rails and sleepers	220
Steam and air pipes, with connections	150
Buildings and foundations	200
Allow for incidental expenses	100
	£1,520

For two or more machines the cost of plant would have to be only slightly increased, as the compressing power would be ample for such increase.

COST PER ANNUM (240 WORKING DAYS.)

Interest on £1,520 at 5 per cent.	£76
Depreciation of machinery at 5 per cent.	76
Repairs on machinery	50
Stores, including steel for cutters, etc.	50
Coal for steam boiler, 540 tons at 3s.	81
Smithy coal, files, and other tools	9
Fireman or boiler stoker	52
Blacksmith for sharpening cutters, etc.	50
Wages for three men and a boy for holing 38,400 yards lineal, being 160 yards per shift for 240 days, at 30s. per shift	360
	£804

In 240 working days 38,400 yards were cut in the seam, which averages from 22 to 28 inches; say, 25,600 tons, at 7½d. per ton, left ready in face for fillers.

These figures had given him a basis for estimating the cost of introducing the machine into some of the thicker seams here, where he considered that, at a distance of 400 yards in-bye as in Scotland, a saving of over 50 per cent. would be effected.

In answer to questions from different members, Mr. MORISON stated, that the quality of coal was very hard and totally different in texture from any that was found in this district. [Members who had examined a large and handsome specimen that was exhibited in the Hall, pronounced it similar to the North Country Low Main, but slightly harder and more brittle.] The 1s. 6½d. a ton mentioned as the cost of hewing and filling the coal, was equivalent to the hewers' wages here. It included filling the coal into tubs at the gateways, ready to be transported from the face, but it did not include any underground transport.

Mr. BRECKON asked if the meeting could have any idea of the percentage of large coal as worked by the machine compared with the percentage by hand labour? That seemed an important part of the question, as far as the coal trade at present was circumstanced.

Mr. MORISON—The proportion of round coals to small got by the machine is as twelve to twenty; that is, with the machine, out of a score of twenty tubs twelve are round. In a part of the pit where the seam is thirty inches, there is less than one-half round coal got by hand holing; that is, by hand labour, out of every twenty tubs in a thirty-inch seam there would be about nine tubs of round, as compared with twelve tubs by machine in the twenty-two inches district.

Mr. LAWRENCE said, that Mr. Morison's experience had gone to show the great utility of the machine in working excessively thin seams, seams indeed which were so thin as almost practically to preclude their being worked by hand, and this he considered to be the great advantage of coal cutting machinery, inasmuch as they enabled a reasonable percentage of round coal to be obtained from seams which would yield almost nothing but small if worked by hand in the usual way, and hardly allow them to be worked to a profit at all. Mr. Breckon, however, he understood to ask, what would be the increase of large coal in seams such as they had in this neighbourhood, which were capable of being profitably hewn by hand? He would be obliged, also, if Mr. Morison would give him some explanation as to the mode of filling; the large sample of coal exhibited appeared to him to be the full thickness of the seam, less the 3¼ inches taken out

by kirving, and he could not see how men who necessarily had to work on their hands and knees could possibly fill such large pieces unless a considerable part of the roof was taken away.

Mr. MORISON, in reply, stated that the gateways, which were about 12 yards apart and led direct to the face, were made of sufficient height to carry the tubs. As the machine went along kirving the face, the coal was kept from falling by wedges, and when the kirving had been completed these wedges were removed. The coal was then cast to the tubs in the gateways, where there was more height, and the 1s. 6½d. per ton included this amount of throwing back, which, of course, would never exceed 6 yards. The coal cutter is on wheels which run on rails. With regard to the amount of large coal produced, he would draw their attention to the fact that if a seam of the thickness of the one he had visited at Penston could be worked by hand, which he very much doubted, they would hardly get any round coals at all, because in a kirving of 3 feet 4 inches deep, about 16 inches in height of coal would have to be hewn out to waste in the fore part of the kirving, whereas the kirving the machine made was only 3¼ inches deep from the front to its extreme depth.

The CHAIRMAN asked what Mr. Morison meant when he said that for a certain length of time the stoppage was out of the control of the machine ?

Mr. MORISON said, that that was when through some mistake on the part of the men at the surface the cutters sent down had not been tempered, and also the meal or "bait" time.

The CHAIRMAN asked if there was any reason why there should be 50 per cent. of the time lost if everything was going smoothly ?

Mr. MORISON said, it took nearly half of that time to change the rails from back to front, and to renew the cutters, which would scarcely be called lost time.

Mr. LAWRENCE said, that his experience of coal-cutting machines —and he had seen a great many—was something like that described by Mr. Morison ; half the time was lost. If they could get machines to go straight ahead without so many hitches, they would certainly then have a very good account to give of them. He did not understand Mr. Morison to mean that the men only worked three hours out of the six, and in the other three took their bait ; but it did seem strange that the machine worked only half its time. Those who had been down in these narrow seams and seen machines at work knew the difficulties under which the men laboured ; and, therefore, even considering that the machine worked only three hours out of the six in such a narrow seam, he thought it

compared very favourably with some machines which he had seen, which worked perhaps half-an-hour out of the six.

Mr. WEEKS thought the great mistake which was made was, that they wanted the coal-cutting machines to traverse too much ground. He believed that by employing more machines they would have better results than by having one machine and working it at a rate that was unsuitable to its strength and structure.

Mr. MORISON said, in conclusion, that what he considered the best practical test of the machine was, that at Penston for five days a week—and he believed for nearly two years, certainly for over eighteen months—they hewed 100 tons of coal every night with this one machine; and even if the height were sufficient for a man to work in, it would take a great many men to do the same amount of work.

The CHAIRMAN then proposed a vote of thanks to Mr. Morison for the additional information on the important subject he had laid before them, which was unanimously carried, and the meeting then terminated.

PROCEEDINGS.

GENERAL MEETING, SATURDAY, APRIL 5, 1879, IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE.

G. C. GREENWELL, Esq., President, in the Chair.

The Secretary read the minutes of the last General Meeting and reported the proceedings of the Council.

The following gentleman was elected :—

Student—

Mr. Kenneth Macrae Davis, Towneley and Stella Collieries, Ryton-on-Tyne.

The following were nominated for election at the next meeting :—

Ordinary Member—

Mr. Arthur Lawrence, Mining Engineer, 72, Crockherbtown, Cardiff.

Associate Member—

Mr. Douglas M. Bell, Rope Manufacturer, Hendon Ropery, Sunderland.

The President then read his Inaugural Address as follows :—

THE PRESIDENT'S ADDRESS.

GENTLEMEN,—In the address, which, by the honour you have conferred upon me in electing me your President, you have permitted me to present to you, I propose, in the first place, to take a general retrospect of what has been done in the last twenty-six years, in order to ascertain if the programme laid down for itself by the (then) North of England Institute of Mining Engineers has, so far, been successfully followed, as regards the results sought to be obtained; and, in the second place, to consider that programme in connection with certain other arrangements by which its progress may be still further increased. It is not my intention to enter into any questions in which matters connected with capital and the employment of labour, in their relationship to each other, as such, are involved. In the early stages of the Institute when the majority of its members were living under its shadow, and when it might be supposed that home interests might have allowed the introduction of such subjects, little, if any, reference was ever made to them; the present condition of the Institute, numbering among its members representatives of the mining and mechanical interests of even more than the United Kingdom, entirely precludes them. We may consider the condition, capacity, and economical application of the powers of those employed; and we may also consider the mode of effecting economy in mineral production as regards the establishment of plant, the manufacture of machinery, and the adaptation of such appliances as are connected therewith, without in any way taking into our consideration any other question relating thereto, except as regards the promotion of such an employment of each as will conduce to the most advantageous application of all; and this is the task, Gentlemen, which we have imposed upon ourselves the duty of performing. Much has been done, to which many most able papers communicated to this Institute bear unequivocal testimony, but much more remains to be done; and such is

the onward march of science, such are the discoveries by which we are almost daily startled, that it will require our most assiduous endeavours, in availing ourselves of their application to our own circumstances, to keep pace with them.

We have two elements to deal with; one of them we can apply as we will—Capital; and the other we can only apply in a qualified degree—Labour. I will not, as previously stated, attempt to define the relative value of each, but merely endeavour to show the condition in which each should be placed so as to produce the best combined result from both. To what extent is this condition attainable, so far as comes within the province and scope of this Institute? That is our present problem. Labour, in order to perform its part rightly, should be efficient in the highest degree, and to this end it should be enabled by the application of capital to exist under such primary conditions as include—

1. The greatest practical security for the life of the workman.
2. The most skilled education of the workman.
3. The greatest economy in the application of his time and energy.

1. *The greatest practical security for the life of the workman.*—What has already been done in order to attain this object, and which has to a large extent been due to the exertions of this and of kindred institutes, will be seen by the following comparison between the state of things in existence previous to 1852, when this Institute was formed, and that at the present time.

In the year 1851 there were employed above and below-ground in the collieries of Great Britain 216,217 persons, and of these 1 out of every 219 persons employed met with a fatal accident; or there were 4·566 deaths to every 1,000 persons employed. In the year 1877 the number of persons employed in the mines of Great Britain and Ireland was 494,386, and the proportion of deaths was as 1 to 409, being 2·445 deaths to every 1,000 persons employed. And this result is not that of an exceptional year. In 1874, the ratio was 1 death to every 510 persons employed, and in 1876 it was 1 to 551.

In the ten years previous to and including the year 1860, the ratio of deaths to the number of persons employed was as 1 to 245, or at the rate of 4·081 per 1,000.

In the ten years previous to and including the year 1870, the ratio of deaths was as 1 to 300, or at the rate of 3·333 per 1,000.

And in the seven subsequent years to and including the year 1877, the

ratio has been as 1 to 443, or 2·257 per 1,000, or about one-half of what it was in 1851. It is earnestly to be hoped that this proportion will still be largely diminished.

When we find that the loss of life from explosions of fire-damp in 1851 was in the proportion of 1 to every 673 persons employed, or 1·486 to every 1,000; that in the ten years ending with 1860, the proportion was as 1 to 1,008 persons employed, or 0·992 to every 1,000; that in the ten years ending with 1870, it was 1 to 1,408 persons employed, or 0·710 to every 1,000; and that in the seven years ending with 1877, it was as 1 to 2,671, or 0·374 to every 1,000 persons employed in mines, or about one-fourth of what it was in 1851, we have, I think, fair ground for congratulation, especially when we reflect upon the fact of so much of the coal produced during the last quarter of a century having been worked out of the maiden districts of the most fiery coal-seams of the kingdom, and perhaps of the world, and that this is the class of accident which, above all others, is that least under control. The above results are obtained from the excellent and highly instructive table contained in Mr. Dickinson's (Inspector) Report to Her Majesty's Secretary of State for the year 1877, recently published.

Without going so minutely into detail in other matters, it appears desirable to make a few further extracts.

Whereas the deaths from "roof and sides falling" have, in 1851, as compared with 1877, diminished from 1 death to every 661 persons employed, or 1·513 per 1,000, to 1 death to every 1,103 persons employed, or 0·906 per 1,000; and that the deaths in "shafts" have in the same years fallen from 1 death to every 987 persons employed, or 1·023 per 1,000, to 1 in 3,832 persons employed, or 0·261 per 1,000, we have again, I think, fair grounds for congratulation.

The deaths from "miscellaneous accidents under-ground" have, in 1851, as compared with 1877, increased from 1 death, in 1851, to every 2,961 persons employed, or 0·337 per 1,000, to (in 1877) 1 death to every 2,643 persons employed, or 0·378 per 1,000; and the deaths from "miscellaneous accidents above-ground" have in the same years of comparison fallen from 1 death to every 4,914 persons employed, or 0·203 per 1,000, to 1 death for every 5,014 persons employed, or 0·199 per 1,000.

In these two latter cases there has not been any improvement; but it must be borne in mind that these belong to classes of accidents far more under the control of the persons who suffer by them than those others, the protection against which falls to a large extent within the province of capital and its immediate agents.

That the two last items referred to occupy no insignificant place in the entire category is seen by the following percentage position of each of the five classes analysed:—

1. Fire-damp explosions	21·65		
2. Roof and sides falling	39·17		
3. Shafts	16·46		
		77·28	per cent.
4. Miscellaneous under-ground	15·88		
5. Do. surface	6·84		
		22·72	,,
		100·00	

When in the year 1835 the late Mr. Buddle gave evidence before a Select Committee of the House of Commons on accidents in mines, he gave it as his opinion that the loss of life in the North of England, from ordinary casualties, must be very nearly equal to that occasioned by explosions of fire-damp (Evidence, 2,378). Mr. Buddle, from his large opportunities of possessing knowledge of the facts, and from his well-known habits of accurate observation, would in all probability be not very far wrong in his conclusions. Unless, therefore, since those days the loss of life from explosion has enormously diminished, that from other casualties has enormously increased, but this, ascertained facts absolutely disprove.

On careful consideration of what I have already brought before you, Gentlemen, I think that it must be candidly admitted that very great steps have been taken in the direction of bringing about that security of life so earnestly to be desired; but at the same time it is none the less incumbent upon us to leave no stone unturned whereby that security may be much further promoted.

We have seen that the loss of life from all causes during the year 1876 was 1 to every 551 persons employed, or 1·815 deaths per 1,000 persons; and I take that year, not because it happens to be the most favourable, but because it allows a comparison to be made between the casualties of mining and those affecting life at sea.

In the year 1876, the loss of life in the merchant service by *drowning alone* was 1 to every 87·503 persons employed, or 11·428 per 1,000. Of the above, the loss of life by drowning, occasioned by wreck, was 1 to 160·580 persons employed, or 6·227 per 1,000; and by other accidental drowning, 1 to 192·292 persons employed, or 5·202 per 1,000. And this was not an exceptional year, for the average of the ten years ending 1875 gives the following death-result, by drowning only, in the merchant service:—

By wreck, 1 to 119·990 persons employed, or 8·3 per 1,000
By accident, 1 to 189·044 „ „ or 5·3 per 1,000

Total, 1 to 73·401 persons employed, or 13·6 per 1,000

And this by no means represents the proportion of the number of deaths by accident at sea to the number of those employed, for the above only includes casualties by drowning, and is exclusive of deaths occasioned by other causes, and is exclusive of "masters."

The Report of the Registrar-General, recently issued, does not furnish us with the deaths from other causes, but these must largely augment the grand total. Even in the Royal navy the loss of life by drowning alone was, in 1876, 1 to every 849·245 persons employed, or 1·2 per 1,000; and in the same year the number of lives lost by other accidents was 2 per 1,000, making a total of 3·2 per 1,000, or 1 death for every 312·5 persons employed, presumably also exclusive of "masters." The number of deaths in this year was to some extent enhanced by 35 deaths from the boiler explosion in H.M.S. "Thunderer."

The average loss, by drowning alone, in the navy for the ten years ending with 1875, was 1 to every 413·783 persons employed, or 2·4 per 1,000, but this does not, according to the Report which I have quoted, include the number of deaths from other causes than by drowning; but the average of the ten years ending with 1875 is probably nearly double what it would have been but for the lives lost by the "Captain" and "Slaney."

In the further institution of comparisons between the loss of life in mines and those lost in other avocations, I may add, from Mr. Willis' (Mine Inspector) Report for the year ending Dec. 31, 1875, that on the authority of the Board of Trade Returns, in a total of 270,000 persons employed on the railways of the Kingdom in 1874, 1,000 lost their lives. This is equal to 1 death for every 270 persons employed, or of 3·703 per 1,000.

It may, for the sake of comparison, be stated that the number of persons engaged in the above occupations in 1876 was as follows:—

Mines	514,532
Merchant service	198,638
Royal navy	45,010
Railways (1874)	270,000

And from these numbers and the percentages above given, the actual numbers of deaths from various causes can be easily calculated.

We are unable to compare the casualties in each employment further than has already been attempted, because we do not know the number of deaths at sea (in the merchant service) by accidents from other causes than drowning. But the absolute number of deaths by accident in 1876 (exclusive as before stated) is as follows :—

Mines		933
Average of 27 years to and with 1876	1,048	
Merchant service, by drowning only		2,270
Average of 10 years to and with 1876	2,700	
Royal navy, by drowning only		53
Average of 10 years to and with 1876, including loss by "Captain" and "Slaney"	113·5	
Royal navy, by accident, including wounds, injuries, and drowning		144
Average of 3 years to and with 1876	116·21	
Railways (1874)		1,000

There are some most useful conclusions to be drawn from the above statistics; and the first of these, as regards the mining interest of this country, is a most important one, particularly bearing in mind the absolute identity of interest that exists upon this point among all persons connected with mines, from the owner to the trapper, and that first essential to the economy of mining in its true sense, the security of life.

It is not true, as has been asserted, that "the miner produces coal by a severity of labour, and *risk of personal safety*, to which the workman of no other occupation is exposed;" or that "the number of deaths in coal-mines averaged eight or ten times above the general average of deaths by violence from dangerous occupations;" for we see that even in the navy itself, with all its advantages, to say nothing of the merchant service, the ratio of deaths per 1,000 persons employed is in excess of what it is in the occupation of mining, and that in railway employment it is about double.

That there is, on the part of all concerned, an absolute identity of interest in the reduction of mining casualties, is shown by the fact that to all of these casualties (see reports of Mine Inspectors, *passim*), the managers of mines are equally exposed with those whom they employ; and, as is well known, the management is in numerous instances held by the owners of mines themselves, who thus have personal, as well as pecuniary, reasons for doing their utmost to prevent them.

Having now brought before you, Gentlemen, an accurate statement of things as they have been, and are, I beg to be allowed, following up the

line which in my address to you, I have laid down for myself, to make a few remarks, and with them a few suggestions as to the bearing of the same upon what may be done in the future, with a view of making mining life still more secure.

It will have been observed, no doubt, that serious individual catastrophes have swelled the average loss of life in the navy: the same applies to the merchant service, and the same applies to mining, though not to persons employed on railways.

Save and except as lessons for our instruction, this Institute has nothing to do with any of these services but that of mining, and the others having served their object may now be dismissed from further consideration at this time.

When we look at the occasional and too frequent large loss of life caused by one explosion, may we not ask:—Are we not, to use a homely expression, putting too many eggs in one basket? Especially considering a most important question which has been brought before us, namely, that by reason of the atmosphere of a coal mine being so impregnated with impalpable coal dust, that which would otherwise be probably a local fire may be merely the match which produces a thorough blast? Is it not reasonable to conclude that the more extensive the mine, and the larger the number of persons employed, the larger amount of ventilation required in consequence will be more likely to have the effect of stirring up such a loaded atmosphere? I recollect an occasion when by reason of one half of the workings of a large and fiery colliery being temporarily drowned up, the remainder was worked double shift, coals being worked twenty-four hours per day instead of twelve. I have not forgotten the anxiety of that time, nor the expression of the underviewer, one of the best pitmen I ever knew, that "the pit had never time to cool." I think no one will deny that additional safety must result from the gas drainage of even a few hours previous to the next breaking off of fresh coal. Is it right, even when there is no such reason (I do not say necessity) as in the above case, so to work collieries that "the pit has never time to cool?" Simply from the safety point of view, is it right to employ at any one time a greater number of persons than practical and experienced men know are sufficient to perform a given amount of work, when that number, by appliances within our reach, can be reduced by the substitution of machinery of different kinds to do that work now executed by manual labour?

The above questions, and others which might be well considered, are such, as regards arrangements, as fall entirely under the control of capital, and all of them are within the province of mining engineers. They are all

more or less connected with those accidents which arise from explosions of fire-damp; and due attention to them might, I think, lead to beneficial results. As to the other four classes of accident, they seem to admit of a division under two heads; one in which the appliances are supplied by the employer, and their application is in the hands of the employed; the second which, to a large extent, the employed have to exercise their own skill and caution to guard against, and it is under this latter head that no improvement has taken place; and this leads me to—

2.—*The most skilled education of the workman.*—I very much doubt if this kind of education can be attained except by commencement in the mine at a comparatively early age. The skilled education of the miner is a very different sort of thing from the education given in ordinary schools, and is more akin to that successfully given on board of training ships with the object of making efficient seamen. In the latter case the training is not given with a view to the service of those trained being made a source of profit, and in consequence, with the training, can be given other, and especially social, education, of which, as essential to the best result, there cannot, I think, be any question as to the great advantage. What I wish to convey is this: that if, in the earlier years of those intended to become miners, they are to have their time and mind occupied with the work of school, they cannot, even if partly employed in the hurry and bustle of mining life, learn that "wide-awake-ness," to coin a word, which is in after-life the pith and marrow of a good pitman; and the converse is equally true.

I dare say the idea of a "training colliery" in each district would be a somewhat novel one; but I do not think that it is any less capable of being worked out than that of training ships. If properly trained by such means, there is no reason why boys should commence colliery work in earnest before the age of fourteen or fifteen. To train all would be probably impracticable, but the training of a considerable number would elevate the whole. I believe that when the whole of the advantages of combining school education with the boy-work of the miner come to be properly balanced with the disadvantages derived therefrom, it will be found that a step has been made in the wrong direction as regards the production of the skilled miner.

3.—*The greatest economy in the application of his time and energy.* The attainment of this is what must to a large extent necessarily follow upon the attainment of the two first conditions. The workman who feels that during his employment his life is secure, and who has that amount of skilled training and acquired experience which enables him, in the greatest

possible degree, to avail himself of the time at his disposal, is undoubtedly the nearest to that condition in which he can do the largest amount of work with the most comfort and advantage to himself, and in the best and most workman-like manner. He will be able to guard more carefully against those accidents, the security against which depends in so great a degree upon his own intelligent care and attention. He will have attained a better position socially, and will in consequence have a greater amount of self-respect, and will lead a more orderly and better-regulated life; and he will, much more than at present, be able to feel with the old soldiers of the Great Napoleon, that "he carries a marshal's baton in his knapsack." Now, Gentlemen, there is here no clashing of interests; the position of the marshal is not lowered because able men are allowed to rise to his level from the ranks. The higher class education and training of the mining engineer will always enable him to occupy the position for which he has been intended, provided always that he fail not in other respects. The opportunities of those without such advantages are now comparatively few; but I cannot help thinking that such opportunities, if even much more frequent than they have hitherto been, would be attended with great advantage, if in no other respect than that they would operate as a spur to the exertions of those who have commenced life under more favourable auspices.

It cannot, I think, but be gratifying to the members of the Institute to have such accounts of other coal and mineral fields, both at home and abroad, as have, from time to time during the course of last year, been presented to them; as instance, "An Account of the Condition of the Mining Industries of Prussia in the year 1875," by Mr. J. B. Simpson; "Notes on the Geology of the Bristol Coal-field, with special reference to the Gloucestershire Basin," by Dr. Walter Saise; "On the Perran Iron Lode in Cornwall and the Mines of the District," by Mr. Charles Parkin; "A Geological Sketch of the Northern Coal-field of France," by Mons. Henry Laporte (read by Mr. G. A. Lebour); "On the present Condition of Mining in some of the principal coal-producing Districts of the Continent," by Mr. T. Lindsay Galloway; "On Canadian Coals, their composition and uses," by Mr. Edward Gilpin. We cannot all be travellers, and those who stay at home and have their sphere of observation confined to their own immediate neighbourhood, are very largely benefited by such information, and it is to be hoped that the volumes of the Transactions will frequently be enriched with such contributions as these. At the same time, we must steadily bear in mind the objects for which the Institute was established; these were, "to meet at fixed periods and discuss the

means for the ventilation of coal mines, for the prevention of accidents, and for general purposes connected with the winning and working of collieries;" and however desirable it is that we should have brought before us everything connected with mining in its most extended view, we must not, at the same time, forget to give its due share of attention to its practical element.

As regards colliery explosions, a very important question has recently been raised as to their connection with the impalpable coal dust which floats in the atmosphere of collieries, and especially of those in which dry and dusty seams of coal are worked. This question has been brought before the Royal Society by Mr. W. Galloway; it has also received the attention of the mining engineers of the Continent, and has also formed the subject of a paper, communicated by Professor A. Freire-Marreco and Mr. D. P. Morison, to the Chesterfield and Derbyshire Institute of Mining, Civil, and Mechanical Engineers, and of one more recently communicated to us by the same gentlemen.

Those who have examined the workings of collieries after explosions have occurred cannot fail to have been struck by the following facts which are of frequent occurrence:—

1. The large area affected by the fire, frequently including the general workings to a greater or less extent.
2. The very frequent entire absence of explosive atmosphere in any part of the workings, notwithstanding the derangement of the ventilation.
3. The quantity of charred coal dust that is found covering the props and the floors and wall-sides of the drifts and excavations.

The above certainly lead us to the conclusion that it was not the actual condition of the mine previous to the explosion as regards fire-damp, which was the cause of such a wide-spread fire. What part is performed by coal dust and what part by fire-damp, possibly given off with great rapidity during even the short period of the explosion, is at present hidden from us. That coal dust should suddenly be ignited by flame, distilled into gas, and exploded simultaneously over miles of excavations, is not easy to realize, although it may be capable of ocular demonstration that it will do so in a box; it is a case in which I fear laboratory experiments will fail us. We are by no means absolutely certain as to the temperature at which fire-damp will ignite; we know that coal gas will ignite at a much lower one; but have we considered the result from a distillation at a low temperature of that impalpable dust which we have under our notice? Not gas in its purified state, but with

all of its highly inflammable adjuncts? And not cool, but at the temperature of distillation? Will this fire at a Davy-lamp, not at but under a red heat? Have we thought whether or not the sudden compression (produced by an explosion) of the loaded atmosphere into the *culs-de-sac* of the workings might produce sufficient heat not only to distil the dust but to ignite the product? We must on these points carry our investigations much further. They are of such most serious importance that they should form the subject of special and exhaustive enquiry with experiments as far as possible on a practical scale, to be made by a committee similar to those which have been from time to time appointed to investigate the important questions of under-ground haulage, safety-lamps, ventilating, machinery, &c.

Many years ago, when the chief employment of coal was for purposes to which screened coals only were mainly applicable, immense quantities of small coal, for which there was no sale, were annually consumed on the fiery heaps of these and other districts. As manufactories increased, the small coal obtained a market which, to a large extent, it still maintains. The requirements for large or screened coals, however, appear to be greater than those for the small coal, without which they are not produced; and there appears at present, and probably for some time to come, to be a likelihood of a recurrence to those "burning shames" of the past. Those of you, Gentlemen, who have visited the collieries abroad, will no doubt have observed with great interest the manufacture of fine small coal, by mixing it with a little pitch and compressing the mixture in a plastic state produced by heat into moulds, into what are called briquettes, suitable for those purposes to which large coal is applied. This is a subject to which, I think, we may well direct our attention, particularly as by such manipulation the whole of the valuable mineral which we bring to the surface by so great an expenditure of capital and labour may be utilized. I need not remark that if by this process we can convert worthless small coal into a fuel as valuable, or nearly as valuable, as large coal, at a cost much less than that of producing large coal, a lower rate of exhaustion of our coal-fields and an equal or greater return for our capital would be the result, because thus the same quantity of useful fuel would be produced by a less expenditure of capital, labour, and of our natural resources.

The discoveries which have been recently made in the production of the electrical light seem almost to hold out a hope to us that we may have mines lighted by its agency much more effectually and safely than at present. This is a question all possible information upon which we ought to obtain with a view to seize upon anything which may be made available for our special requirements.

Many of us no doubt remember the assertion of a distinguished philosopher, that no steam vessel could ever carry coal enough to steam across the Atlantic; and many of us may have heard of the saying of Sir Humphrey Davy, that when London was lighted with gas he should expect to see St. Paul's and Westminster Abbey shake hands! But who in these days will be found to doubt or question the marvellous resources of science and its power to apply to practical use those secret powers of nature, of the very existence of which we have scarcely even dreamed? Gentlemen, we have been born fifty years too soon!

Mr. LINDSAY WOOD said, he felt sure the members would join with him in passing a vote of thanks to their President for his very instructive and able address, in which was so much that would require the serious consideration of the members, and which, he had no doubt, would cause them to produce appliances which might tend still further to the saving of life, an object the Institute always had in view, and which he considered it had very materially contributed to effect. He thought the statistics which the President had given were most instructive, and he felt sure that, through the instrumentality of the Institute, the saving of life would be still greater than it had already been. He therefore asked the meeting, without further comment, to join with him in a vote of thanks to the President.

The motion was then put and carried by acclamation.

The PRESIDENT said, he was extremely obliged to the members for the very high compliment they had paid him in having received his address in so flattering a manner.

The PRESIDENT then announced that Mr. D. P. Morison's paper on "Schmitt's Revolving Spiral Screen" was open for discussion, and asked Mr. Morison whether any of the screens were at work in England?

Mr. MORISON said, he did not think they had been introduced into this country, but Mr. Danson, who had kindly supplied him with the information contained in the paper, was present, and had some particulars connected with the screen to communicate to the meeting.

Mr. DANSON said, the screen, the model of which was before them, was not at work in this country. It had been introduced in Germany,

on the Ruhr, and the results contained in the paper read to the Institute at the last meeting, by Mr. Morison, were taken from screens actually at work in competition with the ordinary revolving screen, which is also used, and which the present screen, from its superior results, appeared likely to supersede.

Mr. W. STEADMAN ALDIS then read the following paper "On the Mathematical Theory of Amsler's Planimeter."

ON THE MATHEMATICAL THEORY OF AMSLER'S PLANIMETER.

By W. STEADMAN ALDIS, M.A.

THE writer's attention having been called to the mathematical theory of Amsler's Planimeter by gentlemen desirous of becoming more conversant with the principles on which its accuracy depends, he has endeavoured to elucidate the subject in a short paper.

An account of this instrument has been given in a paper by Mr. J. Bramwell, published in the British Association Reports for 1872, but this account is rather a description of its mechanical construction than an explanation of the mathematical principles on which it is constructed. Another account of the instrument, which appeared in Spon's Dictionary of Engineering is, in substance, the same as the one now given, but as some of the details are differently treated, it is possible that the present attempt to further illustrate the theory of the construction of the instrument in an elementary manner may not be without interest to the members.

Essentially the Planimeter consists of two straight arms, AB and CBT, Fig. 1. The point A is fixed, and the arm AB can turn freely in one plane about A. The other arm is fixed to AB at B by a pin, round which it is capable of turning in the same plane as that in which AB turns. To one end of this second arm is affixed a tracer T; and at some other point of this arm C is affixed a wheel, which turns round an axis parallel to and beneath CBT, and whose periphery rolls on the plane on which the whole instrument rests. The rim of this wheel is graduated, so that by means of a pointer the amount through which it has turned in passing from one position to another can be read off.

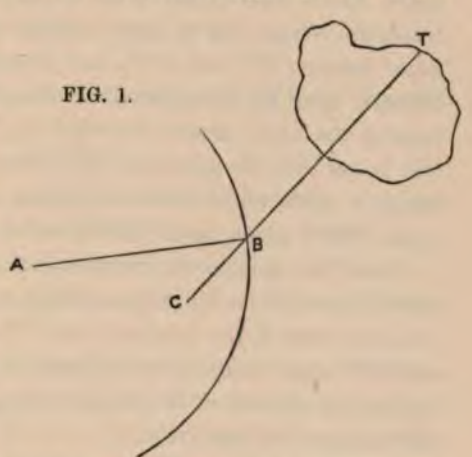
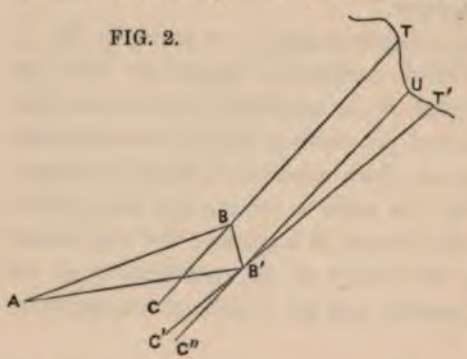


FIG. 1.

The reading of this circle gives the amount of space described by the point C during the motion, the *space being estimated at each instant in a direction perpendicular to the instantaneous position of* CBT. This will be obvious to all who are familiar with the instrument.

The tracer T is made to pass round the periphery of any closed figure. During this process the point B will travel along the arc of a circle whose centre is A and radius AB, travelling in one direction during part of the time and in the opposite during other part or parts of the time, finally arriving at the same point from which it started. The position of the point B can be determined for any given position of T by a process familiar to all draughtsmen, the distances TB and AB being given.

FIG. 2.



Let now TT', Fig. 2, be two consecutive positions of the tracer, BB' the corresponding positions of the pin B. Through B' draw a straight line parallel to BT, to meet the curve traced in U. The area BTT'B' is thus divided into two parts, one part differing inappreciably from the sector of a circle whose radius is B'T' and whose angle is T'B'U, and the other being a trapezium whose area is approximately the product of BT into the distance between BT and B'T', and consequently varying as this latter distance, since BT is constant. During this same motion the wheel will register the whole amount travelled by C perpendicularly to BC. This will be less than the perpendicular distance between BT and B'U by the arc of a circle whose centre is B' and radius B'C', which subtends an angle C'B'C'', which equals UB'T', at the centre.

Now if we imagine the tracer to pass over the whole perimeter of the closed figure, since BT, Fig. 1, finally comes back to the position from which it started, the algebraic sum of the areas of the small sectors such as UB'T' must vanish, since the areas of sectors are proportional to their angles, and the sum of the angles taken positively must equal the sum of the angles taken negatively.

For a similar reason the sum of the arcs of the small circles registered by the wheel must also vanish. Hence the final result registered by the wheel will be the algebraic sum of the distances between all such lines as BT and B'U, Fig. 2; the wheel turning in one direction if B'U be to the left of BT, and in the opposite if B'U be to the right of BT.

It is easily seen that if during the time when T is on the part of the figure in which BT moves to the right we estimate the areas as positive, and during the time in which it moves to the left we estimate the areas as negative, the final sum of the areas described by BT will be the area included by the closed figure.

Hence this area is proportional to the amount registered by the wheel during the whole passage of T over the perimeter of the closed curve.

It is obvious that the final amount registered will be the same whatever the position of C on BT, since the small distances C′C″ disappear from the final result.

These results can be expressed in the language of the integral calculus.

Let θ, ϕ be the angles which AB and BT make with any fixed direction. Then the elementary area TBB′T′, divided into the two parts T′B′U and TUB′B is equal to

$$\tfrac{1}{2}\, b^2 \delta\phi + ba\delta\theta \cos.\ (\phi - \theta),$$

if AB = a, BT = b.

The whole area described will therefore be the sum of all such expressions, or

$$\Sigma\, \tfrac{1}{2}\, b^2\, \delta\phi + \Sigma ba \cos.\ (\phi - \theta)\, \delta\theta,$$

of which the former term vanishes.

The amount recorded by the wheel as the rod passes from BT to B′T′

$$= a\delta\theta \cos.\ (\phi - \theta) - c\delta\phi, \text{ if BC} = c\ ;$$

and the whole amount recorded by the wheel therefore

$$= \Sigma a\delta\theta \cos.\ (\phi - \theta) - \Sigma c\delta\phi,$$

of which the latter term vanishes.

Hence if A be the area of the closed curve, and n the length recorded by the wheel,

$$A = bn.$$

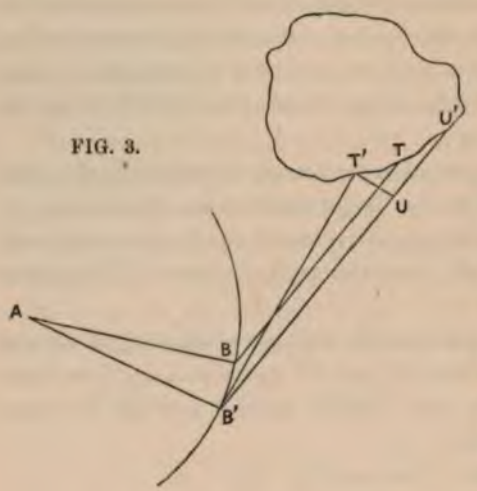
If b and n be estimated in inches, the area will be given in square inches by multiplying the record on the wheel by the length of b.

As above remarked the relation between A and n does not involve c, the length of BC. Hence it is indifferent at what point of BT the registering wheel is placed.

The instrument would record equally accurately if the point B were constrained to move in a straight line instead of the arc of a circle, or indeed in a groove of any convenient shape, so long as the point B in moving along the groove move so as to return at last to its original position.

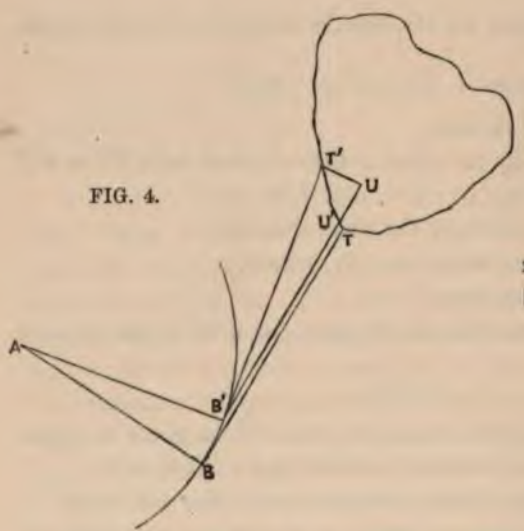
The two following diagrams are added to show various cases of relative position of BT and B′T′.

FIG. 3.



In Fig. 3, the area described is the difference of the sector and the trapezium, the trapezium being still described positively and the sector negatively. The small triangular area T'UU' is indefinitely small *compared with* the other small areas in the figure, and may be neglected in the computation.

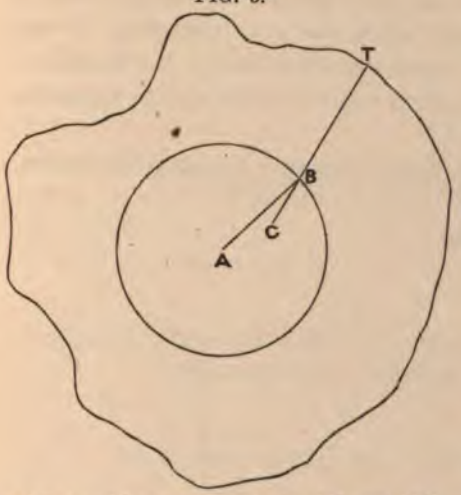
FIG. 4.



In Fig. 4, the trapezium and the sector are both described negatively.

The investigation of the properties of the Planimeter has proceeded on the assumption that the centre of rotation and the arc described by the point B lie entirely without the area to be measured. The instrument can, however, be used to measure an area when the fixed point A is placed within the area, and the point B, instead of passing along a certain arc of the circle and then back along the same arc, is made to describe the whole of the perimeter of that circle.

FIG. 5.



The area described outside this circle will as before consist of a series of parallelograms and a series of sectors. The series of sectors will in this case on the whole no longer cancel one another as before, but will add together and form altogether the area of a circle whose radius is BT. Hence the area inside the closed curve will be the sum of the parallelograms, and the sum of the areas of two circles whose radii are respectively AB and BT.

Similarly the small arcs C′C″, described in the small motions by the registering wheel, will no longer cancel one another, but will add together and form the perimeter of a circle whose radius is CB.

Hence the area described will not now equal the product of the register of the wheel by the length of the arm BT, but will exceed it by a quantity which depends only on the lengths of the lines AB, BC, and BT. If this quantity be estimated once for all, and stamped on the instrument, the planimeter can then be used to estimate areas of such dimensions that the whole instrument is obliged to make a complete revolution within the area in order that the tracer T may pass over the whole periphery.

The arithmetical relation between the area and the register of the wheel is easily seen, by those who have followed the analysis in the paper, to be

$$A = bn + \pi a^2 + \pi b^2 - 2\pi bc,$$

π being the number 3·14159.

If the wheel register one b-th of an inch as a whole inch the register will give the square inches in the area to be added to the given constant.

If the rotation of the registering wheel be such as to give a smaller reading at the end than at the beginning, the quantity n will be negative and must be *subtracted* from the constant number stamped on the instrument.

Mr. G. B. FORSTER said, he had much pleasure in moving a vote of thanks to Mr. Aldis for his paper, which was most interesting. It was a paper which would require a great amount of study; but he had no doubt that when printed the members would be quite able to appreciate Professor Aldis' lucid description.

Mr. MORISON said, he had great pleasure in seconding the motion, and it was carried unanimously.

The meeting then terminated.

PROCEEDINGS.

GENERAL MEETING, SATURDAY, MAY 3RD, 1879, IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE.

G. C. GREENWELL, ESQ., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council.

The following gentlemen were elected:—

ORDINARY MEMBER—

Mr. ARTHUR LAWRENCE, Mining Engineer, 72, Crockherbtown, Cardiff.

ASSOCIATE MEMBER—

Mr. DOUGLAS M. BELL, Rope Manufacturer, Hendon Ropery, Sunderland.

The following was nominated for election at the next meeting:—

ASSOCIATE MEMBER—

Mr. E. T. BAILES, Wingate, Ferryhill.

The discussion of Mr. J. D. KENDALL'S paper, "On the Hematite Deposits of West Cumberland," which had been announced, was postponed, in consequence of Mr. Kendall's unavoidable absence.

PROCEEDINGS.

GENERAL MEETING, SATURDAY, JUNE 7TH, 1879, IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE.

G. C. GREENWELL, ESQ., PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last general meeting, and reported the proceedings of the Council.

The following gentleman was then elected:—

ASSOCIATE MEMBER—

Mr. E. T. BAILES, Wingate, Ferry Hill.

The following were nominated for election at the next meeting:—

ASSOCIATE MEMBER—

Mr. MATTHEW HECKELS DOUGLAS, Whitburn Colliery, Sunderland.

STUDENT—

Mr. SAMUEL HARE, Pemberton Colliery, Wigan.

The discussion on Mr. J. D. Kendall's paper, "On the Hematite Deposits of West Cumberland," was then proceeded with.

The PRESIDENT stated that Mr. Kendall had kindly attended the meeting to-day to give any further information on the subject that might be required, and had brought specimens of various rocks and fossils, taken from the district, to illustrate his remarks. He had read this paper of

Mr. Kendall's with very great satisfaction; first, on account of the large amount of information it contained, and, in the next place, on account of the evident care which had been bestowed upon its compilation, which he was the better able to appreciate as he had himself carefully examined the different districts of the hematite iron ore country. He would first wish to have some explanation of the statement contained on page 115, that the coal measures are divisible into two parts, which are uncomformable to one another, the upper part being named the Whitehaven sandstone. The unconformability of this Whitehaven sandstone with the coal-measures proper, as he would call them, seemed to him to be clearly established, but he very strongly doubted whether the former formed part of the coal-measures at all. In the absence of distinct proof to the contrary, he rather thought that it was a Permian formation. Upon this subject there has, in other places, been much difference of opinion. At Tynemouth, underlying the lower New Red Sandstone (the well-known "sand" which has been the occasion of such large expenditures in sinking through it in the county of Durham), there is a sandstone and also a bed of shale resembling the upper series described by Mr. Kendall. This sandstone and shale are, however, he should consider, a portion of the true coal-measures, coloured by infiltration of ferruginous matter from the formerly overlying, but now denuded, New Red Sandstone. As may be seen, the sandstone contains small nodules of hematite iron ore. In the whole of the English coal-fields which he (the President) had examined, where there is an overlie of Permian formation, the coal-measures for several fathoms subjacent to it are stained red or purple. Where the strata so stained, on account of their unconformability, attain a greater depth below the Permian, they lose these red and purple colours, and present the ordinary character of coal-measure strata. These coloured strata were formerly and erroneously called Lower New Red Sandstone. At Askam, in Furness, the hematite, as he had observed it in 1865, was of the nature of a stratum or bed with a limestone roof and limestone floor, the strata lying in the manner shown in Plate XXXIX., Fig. 1. At this place the dip of the hematite bed was S. 44 W., at the rate of about 1 in 2 on an average, and between the outcrop of the ore and sand above was a bed of what is termed "pindle" or "pinel," of irregular thickness up to 3 feet, and consisting of a mixture of earth and stones. The Pit D was 45 yards in depth, and the drift across the bed from A to B was 45 yards. At E, situated 100 yards from it, a borehole was put down, which proved the ore, at 80 yards in depth, to be 7 feet thick, with a limestone roof and a limestone floor. Differing from the above are

To illustrate Mr. Greenwell's remarks on Mr. J.D. Kendall's paper on the "Hematite District of West Cumberland."

FIG. 1.

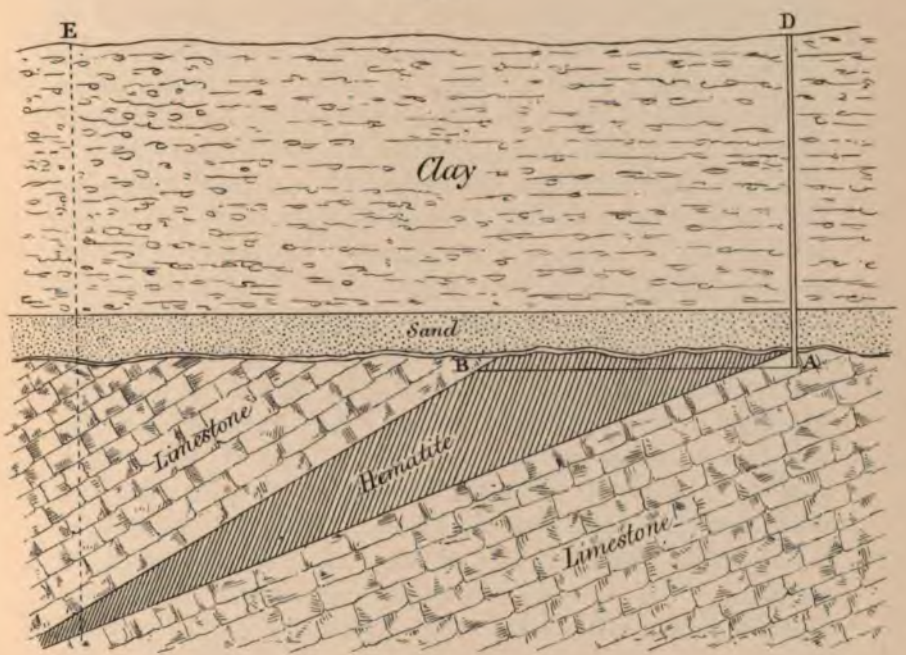
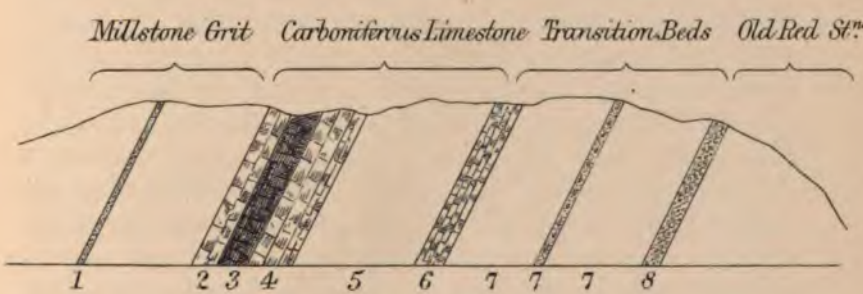


FIG. 2.



1 Sandstone Vein of Iron Ore
2 Whitehead Limestone
3 Limestone Vein of Iron Ore
4 Grey and Red Limestone
5 Black Rock Limestone
6 Fore line Limestone
7 Grey Sandstone
8 Conglomerate

deposits of hematite such as are seen at Mousell in Furness. Several of these deposits have been proved, and that now being worked is brought along a drift 70 yards long in limestone to a shaft, also in limestone, 85 yards in depth. Here the bottom of the "pocket" has not been reached. By the working of the ore out of such pockets on Lindal Moor, the surface has subsided in some places nearly 100 feet, the width of the ore varying from 3 feet to 40 or 50 yards. In working these "sops" or "pockets," small shafts are sunk in the body of the ore, and levels driven in it about 9 feet in height, the superincumbent strata being temporarily supported by timbering. The props decay, and the overlying strata break down. The shafts are then deepened, and other levels driven until the ore is worked out. Hematite is also worked in the Forest of Dean, where it seems to lie in pockets more or less connected with each other, and forming an extremely irregular stratum. One of these series is found in the Millstone Grit and another in the Carboniferous Limestone, as shewn in Plate XXXIX., Fig. 2. The ironstone here, particularly in the limestone, seems to be continuous in a series of "pockets," locally named "churns," in the whole of the formations in which they are found. They have not been worked under the trough of the basin of the Forest of Dean, but having been found under similar conditions on opposite outcrops of the basin, the inference is fair that they will be found there. Experiences in Cumberland seem to lead to a different conclusion so far, but perhaps further investigation may alter present views. At Acton, in Gloucestershire ("Iron Acton," as it is called), a hematite, really a brown hematite, is worked in a semistratum in the Millstone Grit. He had seen this ore, which was of fine quality, and mentioned it now as being somewhat parallel in position to the sandstone vein of the Forest of Dean, and as having been found, when worked at a considerable depth, to have changed into white carbonate or spathose iron ore. This leads to the conclusion that the original form of the deposit was not improbably that of white carbonate subsequently altered to that of hematite or peroxide by the action of atmospheric influence. That such a change can take place is abundantly proved. The greenish iron ore of Westbury, in Wilts is, towards the outcrop, a brownish red; and the naturally greenish-blue ore of Cleveland, when exposed, becomes red also. He wished he could have given some particulars about the state of the hematites at Brendon, in North Somersetshire, where the iron ore is very much in the condition described by Mr. Kendall in Plate XXVII., and in Fig. 2 of Plate XXII., but the change here from hematite to white carbonate takes place at about 50 fathoms from the surface.

Generally, brown hematite has been found near the surface on the Brendon Hills, rarely white, though sometimes this has occurred; but the brown has invariably, at the depth of 100 yards from the surface, become white carbonate. The lodes, as white carbonate, gradually become less in width as depth increases, until, at Raleigh's Cross, both sides of the lode come together, and the mine has been abandoned. The white carbonate contains about 13 per cent. of manganese and 34 of iron; the brown hematite about 8 per cent. of manganese and 45 of iron.

Mr. G. B. FORSTER said, in reference to the specimens of Whitehaven sandstone which Mr. Kendall had brought, he was pretty well acquainted with this sandstone, and had recognised the same characteristics in the stone of the walls near Tynemouth Castle gate; but whether this particular sandstone ran over and was conformable to the coal-measures here or not, Mr. Kendall was perfectly right in stating that it did not do so in Cumberland; and this was distinctly proved by its immediately overlying different seams. He had no doubt this Whitehaven sandstone was equivalent to the sandstone immediately above the coal measures in this district.

Mr. MARLEY asked if Mr. Forster thought it was part of the coal formation proper.

Mr. FORSTER—It is not conformable to the coal formation proper.

Mr. A. L. STEAVENSON thought all must agree with the remarks of the President as to the value of the paper, and the care the author had taken to make it complete. With regard to the first part, it was introductory: the second, which defined the position, formation, and inner nature of the deposits, he thought was especially valuable; but probably the third part, which touched on the age of the deposits, might be a little open to controversy; while the latter portion, which treated of the origin of the deposits, he must say he was inclined to consider as inconclusive. As he (Mr. Steavenson) understood Mr. Kendall, that gentleman considered that there had been a species of transformation, and that what was originally lime had latterly become hematite. The gist of Mr. Kendall's argument seems to be contained in the following quotation from page 148:—"It is known that when certain material elements, or certain combinations of those elements, are brought into contact under certain conditions there takes place between them a chemical reaction. For instance, if a piece of chalk is dropped into a solution of perchloride of iron, there at once sets in a reaction between them; part of the chalk is dissolved, and a red precipitate thrown down in its place. In time the chalk would disappear altogether, and nothing be left but this red pre-

cipitate. Now, that seems to be the process by which the hematite deposits were produced. The limestone, the slate, and the granite were each attacked like the chalk in the above experiment by a solution of iron, by which parts of them were removed and peroxide of iron thrown down in place thereof." Now, he could not help observing that when all the different formations in which, according to Mr. Kendall's own account, this hematite is found, came to be considered—first, the granite, next the Skiddaw slate, then the Borrowdale series, together with the Coniston series, the Carboniferous Limestone, the Millstone Grit, and the coal-measures, he must say that it was very difficult to believe that such a chemical reaction could take place equally between all the rocks. He could quite imagine that in the case of the limestone it might occur, but with such rocks as granite it might well be asked how such a change could be produced; and he saw very great difficulty in accepting the solution proposed. In several papers by such great authorities as Sir Roderick Murchison, Professor Newberry, Professor Harkness, Mr. David Forbes, and others, which had been reviewed by Mr. Kendall, many sources of origin were alluded to, but the process of formation indicated by Mr. Kendall had been alluded to by none of them; and this was to some extent *primâ facie* evidence that such a supposition as to origin could not be altogether supported. Then, again, it was a rather curious fact that there are so many different kinds of ore. If red hematite can be created by such a transformation—and he thought that word met the case best—how was the fact accounted for that it sometimes took the form of kidney ore, and sometimes that of brown hematite? Again, in page 152, we were told by Mr. Kendall with respect to the source of the ore, "that it was primarily volcanic would be admitted without hesitation." How could this be reconciled with the transformation theory? He was obliged, after a careful study of the paper, to confess that he could not follow the writer, and that he did not consider the question had been satisfactorily solved. It rather curiously happened that in December, 1878, the very month and year in which this paper was written, there had been a paper contributed to the *Revue Universelle*, by an eminent Frenchman, who, in speaking of some hematite deposits in Spain, said,* "We think there can be no doubt that these minerals have been deposited by hot inundations during the cretaceous periods. These inundations, strongly charged with carbonate of iron, have filled all the cavities of the

* Vol. IV., Number 3; November and December, 1878.

lime, and the mineral contained therein has formed deposits taking the form of the existing cavities." Then he gives two theories:—"As we have said above, different hypotheses have been hazarded as to the configuration and formation of these deposits. First, we must admit that the bulk of the red ore at first formed part of a horizontal bed, covered afterwards by the psammites (=arenaceous shales and shaly sandstones=grey beds) [stratified shales] and the limestones of the chalk formation. This bed had been thrown up, and by these movements of the soil had given birth to the mountains; then the fissures which took place after this upheaval allowed the passage upwards of those heated inundations which produced the cap of brown hematite. By this hypothesis, the ore would not be found to extend greatly in depth, but would be found under the schists and calcaires which form the sides and beds of the valleys." According to another theory propounded in the same article, it has been thought that after the psammites, grès and calcaires cénomanians were deposited in horizontal beds, these sedimentary deposits had been raised with violence, accompanied with the formation of vast crevices into which were poured the hot water inundations proceeding from central fissures containing the metal, and that these fissures and the subsequent cooling of the water had formed the deposits of ore. The paper he had referred to was on the Mines of Somorrostro, in Spain; and the writer gave geological notes on the subject, at page 660, which clearly disagreed with the views propounded by Mr. Kendall. He (Mr. Steavenson) would be very glad if the theory mentioned by Mr. Kendall should lead to some comprehension of this rather difficult subject. He thought, however, that the value of the hematites in the past would be somewhat diminished by the later development of the Cleveland steel question.

Mr. T. J. Bewick said, he wished to add his meed of praise to that already bestowed by the President upon this really valuable paper; for whether or not the theories propounded by Mr. Kendall were correct, the paper was certainly, he thought, a most valuable contribution to their Transactions, and one which might, if it did nothing further, open the door to a solution of the phenomena described. He (Mr. B.) was ready to admit that the more he saw of the deposits of hematite in Cumberland, North Lancashire, and other places, the more he was puzzled to account for them in the varying positions and conditions in which they were found. He knew some of the mines referred to by Mr. Kendall, and he also knew something of the North Lancashire mines, which, although in another county, were simply a continuation southward of the deposits

described in the paper. He had the pleasure, about a month ago, of examining with considerable care one of the most remarkable deposits in North Lancashire, at the Stank Mine, near Barrow-in-Furness, where there is, at any rate, one very distinct vein or lode passing through the country with a considerable inclination or dip, and with, so far as had been ascertained, a large dislocation, probably many fathoms. This mine is in limestone, overlaid by a black shale; and the vein is said—he could not speak to this with certainty—not to penetrate the shale, but perhaps Mr. Kendall, who knew it very well, would be able to tell them whether it did or not. It bears a very great similarity to an ordinary lead or copper vein, only it is composed entirely of hematite iron ore of a rich character. It is being worked now at a depth of 108 fathoms from the surface; and there is no change whatever in the character of the ore, except that, perhaps, it is a trifle more concentrated or rich at that depth, but there is no appearance whatever of any change from red hematite to any other class of ore. At the side of this vein are large deposits or pockets of fine rich hematite in the limestone, and, so far as he was able to ascertain, without the slightest lead or vein to show that they were in connection with any such geological characteristic. The limestone seemed simply to have been replaced by hematite, and the whole of the roof and sides, so far as had been proved by the workings, was nothing but limestone without anything to account for the ore being there; and he confessed that he could not reconcile these appearances with any theory he knew of. With reference to the deposits in the Forest of Dean which had been alluded to by the President, and some of those in Cornwall which he had seen, they were all more or less of a different character to those in West Cumberland and North Lancashire. Those in Cornwall were simply veins pure and simple in the surrounding strata. There was nothing known there of great pockets in the rock. On the other hand, the ores in the Forest of Dean, the President correctly described them as being without any indication of veins. There were some veins described in the paper which he thought were very similar to those in Cornwall. For example, those in the Skiddaw slates. The same remark applied to others at Boot, in Eskdale. He had been in that mine, and there the deposit was, as he had already described, a vein pure and simple, whereas the deposits in the limestone were not, excepting perhaps in the case of the Stank, the Lindal Moor, and it might be some others, where the ore was worked in distinct veins, although, in addition to these veins, there were large masses of hematite found in the limestone. There was one very peculiar

deposit, which he remembered seeing a few years ago, in North Lancashire, close to Lindal Moor, in the shape of a large mass of fine hematite, without any rock whatever to be seen about it, neither over nor surrounding it. Mr. Kendall told him it eventually was found to rest upon clay slate; but when he (Mr. B.) saw it, it was simply an enormous mass of fine hematite ore surrounded by gravel. He would ask Mr. Kendall if he would explain this. It seemed to him (Mr. B.) almost unaccountable that, where the limestone there rests upon clay slate, this curious mass should be found beyond the limestone in this extraordinary manner. In other places, in similar formations, attempts had been made, and very expensive attempts, to find hematite. It had been found in very limited quantities only, never, he thought, in sufficient abundance to prove commercially successful. In the neighbourhood of Penrith, large sums of money had been spent in borings. The Transactions of the Institute were, by this paper, already very considerably enriched, and he (Mr. B.) would suggest that Mr. Kendall be invited to further extend what he had done for them by adding to this paper another on the North Lancashire deposits, upon which he was equally well informed, and which he (Mr. B.) thought would make a valuable addition to the available references on this important subject. On page 109 the question, as Mr. Kendall put it, was—How did the deposits originate? What is their age? And where are they to be found? Mr. Kendall said that question remained unanswered, and he (Mr. B.) quite agreed with him. They had yet a great deal to learn before they would be able to answer these questions with satisfaction.

Mr. E. F. Boyd said, he might be permitted to add his testimony to the value of this paper. The aim and intention of all geological study and research was to ensure the success of mining operations, and prevent labour and capital from being wastefully expended, and in this sense he felt sure that Mr. Kendall's paper would prove of immense service to the members. Mr. Bewick had said, and very truly, that great explorations and great expense had been undergone in various places; and possibly if this paper was thoroughly investigated, and if the origin of the material and the cause by which it was deposited were clearly ascertained, a great amount of expense in that direction might hereafter be avoided. Before he gave his own opinion as to these deposits, he would ask Mr. Kendall if in any part of these deposits any stratified vegetable remains were found?

Mr. Kendall—None whatever.

Mr. Boyd said, he had asked that question because an answer in the affirmative would have considerably shaken his confidence in the conclusion he had arrived at. He might be quite wrong, but he gave them his opinion for what it was worth, and his opinion was that the deposits were of volcanic origin—plutonic origin—and that the cracks in the strata were the centres, or the conducting points, by which the communication was effected with the central heat of the earth; and that their variety, perpendicularly or horizontally, is varied entirely by the nature, position, and size of the fissures, the more or less rapid cooling of the injected matter, and all the varied circumstances connected with the unequal heat, expansion, electric tension, and mechanical forces which would all play an important part in the cooling of such varied masses so irregularly connected together; added to these important causes of difference, there are those due to the various rocks through which the molten mass has passed; even the Permian, the granite, and the most ancient rocks known, have been and are still subject to these actions, and deposits of hematite are found in every one of them. There was a very ingenious paper read by Mr. John Leithart, "On the Origin of Mineral Veins," at the meeting of the British Association in the year 1838. Professor Sedgwick, Mr. Buckland, Mr. Buddle, and a great number of our own local gentlemen were present when the paper was read, which was a very ingenious attempt to account for the deposition of mineral matter in veins by the action of electricity. The author of this paper remarks "that many other substances besides metals would, when piled in alternate layers, develop electrical action, and became impressed with the opinion that the stratified rocks might be likened to a galvanic battery, and that the peculiar appearances above noticed might receive an explanation upon this supposition provided there was a communication across the enormous 'pile' of rock. Such a communication is made, the author thinks, by mineral veins." Now, this rather corroborated his idea that the deposits of hematite were caused by the same action. There was no reason why both electrical and chemical action should not both be going on at the same time. That electricity is in action when plutonic action is going on there seems to be no doubt; and he was by no means prepared to deny the agency of chemistry, especially as it was found that limestone has a greater attraction for the ore than any other strata, and not at all in opposition to the principle of plutonic action, which, in fact, it might assist in developing or modifying. It was clearly seen in Northumberland that plutonic matter could be laid out so as to appear stratified, for the Great Whin Sill looks to an ordinary observer as a stratified rock

occurring between the limestones and the shales above it, and the limestones and the shales beneath it. There are 90 feet of plutonic matter between the two, and it is perfectly conformable with the ordinary dip of the rest of the strata. But everybody admits that, notwithstanding this, it is plutonic—that it was protruded through the beds. He believed they had had that question very fully discussed by Mr. Lebour and other gentlemen, including Professor Sedgwick and Professor Buckland, who were all convinced as to this theory; and this view of the subject had been very much strengthened by Mr. Lebour in his paper "On the 'Great' and 'Four-Fathom' Limestones in South Northumberland," Vol. XXIV., page 140, and Plate XXXIII., describing the section of a quarry belonging to Sir Walter Trevelyan, who was kind enough to take him (Mr. Boyd) to inspect it from time to time as the quarry workings further developed it, where the limestone overlying the top of the Whin Sill is permeated in many of its horizontal and vertical fissures by the plutonic matter. Mr. Jos. Bewick, in 1857, wrote a paper "On the Ore and Ironstone of Rosedale Abbey." In that paper it was distinctly stated, as the opinion of the author, that the magnetic deposit described was nothing more than a gigantic plutonic dyke, intruded after the deposition of the surrounding strata, which contained remains of sigillaria and stigmaria. But this theory of its plutonic origin was afterwards seriously interfered with, when, in the further working of the magnetic deposit, the sigillaria and stigmaria again appeared in the horizontal layers.

Mr. KENDALL—There are animal remains in the hematite deposits, but not vegetable.

Mr. BOYD said, that was remarkable, and certainly was an argument against his theory; he was not aware of that fact before.

Mr. G. A. LEBOUR remarked, that it always had struck him that each writer and each speaker on this subject seemed to favour the idea that there must have been one universal cause for the formation of these hematite deposits. Now, one did not always see why the deposits which are found sometimes in pockets and sometimes as veins, and sometimes again in faults, or as true beds of hematite, should not be due to different modes of action. Nature does not always do the same thing in exactly the same way. Several varying theories might be perfectly true, each indicating the formation of some of the various deposits; for each deposit, or at all events each set of deposits, might have a peculiar origin of its own, and it struck him that the argument for or against any one particular theory should not be pressed as applicable to all classes of deposits in all districts, but simply as applicable to some one locality or to some one form

of deposit; and he could not help thinking that the facts which Mr. Kendall had brought out in his admirable paper, tended very much to show that there might have been a variety of causes for the deposition of hematite, and that one theory alone would not account for the whole. He had been particularly glad to see that Mr. Kendall himself unconsciously favoured the idea of variety in the modes of deposition, insomuch that he some years ago, in an equally valuable paper, favoured a view somewhat different to the one which he brought forward in his present paper. But he (Mr. Lebour) thought that the fact that one so competent should have had two theories on the subject was, to a certain extent, an admission that there might be more than one special cause in bringing about these deposits, and that, whether they be attributable to electricity, as Mr. Boyd thought, or whether they had been deposited from water or caused by igneous action, or whether all or several of these agencies might not have contributed to them in varying proportions in different localities, it would at present be difficult to determine.

Mr. Wm. Cochrane said, he would like to ask Mr. Bewick whether the deposit of ore coming off the vein was of similar character to that found in the "flats" of the lead mines; and whether the limestone in contact with the deposit presented the appearance of having been impregnated with the intruding substances?

Mr. Bewick said, that with regard to Mr. Cochrane's second question, there was nothing to lead him to suppose that the iron ore found on the edges of these large deposits had been limestone altered by any circumstance whatever. Sometimes in the middle of a mass of iron ore a large irregular shaped piece of limestone might be found not connected with the other part of the limestone, but simply a large boulder of limestone in the heart of the iron ore. With regard to the first question, so far as the quality was concerned he did not know that there was any difference, but if there was, he thought there was more of the soft iron ore in the pockets and of the hard ore in the veins.

The President said, that in the brown hematite in the Forest of Dean in some places there was almost as much limestone as hematite in the same pocket.

Mr. Bewick—Yes; and he did not think the Cumberland iron ore could be compared with that found in the Forest of Dean, which was considerably more stratified than the former.

Mr. Marley said, he had not read sufficient of Mr. Kendall's paper to do justice to it. He was very glad, however, that they had got a pioneer paper upon hematites. Mr. Bewick and himself had often

endeavoured to get gentlemen to write a paper upon the subject. He had proposed, like the President, to call attention to what the writer said on pages 115 and 116 as to the nonconformability of two beds of the the same coal-field. He agreed with the President that they were not portions of the same coal-field, and he was quite convinced that the upper bed did not belong to the coal formation proper. He had had a good deal of experience in the Cumberland hematite mines, and the more he had had to do with them, and also with the mines in Lancashire and in Scotland, and in one single instance in Dalmatia, the more was he convinced that no one as yet had perfectly penetrated the mystery of the formation of the deposits; and he thought, that having now got one paper upon the subject, perhaps other gentlemen would follow the example which had been set by their President and jot down a few notes giving the opinion each had formed from his own experience. He thought they would be able to understand a good deal better as to what might be the cause of the deposits if they would divide the inquiry into two parts, and consider not only what was the cause of the hematite ore, but also what was the cause of the cavities in which the ore has been deposited. As to the "Magnetic Iron Ore of Rosedale Abbey," alluded to by Mr. Boyd as being a plutonic dyke, he would refer to his paper thereon in Vol. XIX. of these Transactions, in which that gentleman drew opposite conclusions.

Mr. KENDALL said, with reference to the remarks made by the President and Mr. Marley as to the unconformability of the upper part of the Whitehaven coal-field, he thought the facts brought forward in the paper were sufficient to show that there was such unconformity; and as to its forming part of the coal-measures, he might state what he had not stated in the paper, namely, that at one part of the field there has been a seam of coal worked in it; also, that the organic remains which had been found in it are coal-measure forms, and he might say, it was the opinion of the geological surveyors now in this district, who, after having gone over the whole district—over a much larger area than he himself had had the opportunity of going over—were of opinion that it was a portion of the coal-measures. Neither the President nor Mr. Marley state their reasons for holding the opinion that the Whitehaven sandstone does not belong to the coal-measures, so that he was left to guess it. The only reason that he could think of as likely to weigh with them is the unconformability of those rocks to the coal-measures proper. But if unconformability is a sufficient reason for not classing the Whitehaven sandstone with the coal-measures, it is also a sufficient reason why we should not look upon that rock as Permian, for it must not be forgotten that the Whitehaven

sandstone is unconformable to the overlying Permians as well as to the underlying coal-measures. Were it necessary, he might adduce a number of authorities in support of the coal-measure age of these rocks, but it is perhaps best in this, as in most other cases, to rely rather upon fact and argument.

As to the remarks of Mr. Steavenson, he was scarcely able to say much, because so far as he understood, Mr. Steavenson simply said that he did did not believe that his (Mr. Kendall's) explanation was competent to explain the facts. Mr. Steavenson did not disprove it, for he did not bring forward either facts or arguments on the opposite side, but rested on an unsupported assertion. The pith of the paper was in the attempt to prove that the ore had been formed by replacement, and he thought the number of facts which had been brought forward in reference to the deposits were sufficient to convince any one that this must have been the case, whether the iron by which the replacement was effected was in the form of a chloride or a carbonate. Mr. Steavenson appeared to be labouring under a misapprehension in calling the process a transformation. It is not a transformation at all, but simply the removal of *one substance* and putting *another and altogether different substance* in its place. That the ore was formed by replacement is a deduction from geological premises, which, he submitted, in the case of the deposits in the limestone is perfectly conclusive and logical. In the other deposits the evidence of such a mode of origin is of a different kind, but still, he thought, quite as conclusive. A fact not stated in his paper, but which he had often observed at Boot and Kelton Fell, is the occurrence in the ore of large lenticular and flag-like masses of country rock, which have no connection whatever with the "cheeks" of the lode, but yet have the same "hade" as the lode, in fact, are parallel to the cheeks. Now, if these pieces had fallen from the "cheeks" as the ore was being deposited in a fissure, they surely, at any rate many of them, would have fallen on their side, for most of them are of such a size that they could lie crosswise in the vein. Then again, a specimen on the table, and figured on Plate XXIII., Fig. 4, was very peculiar too; in a matrix of hematite there are pieces of slate which send out very fine threads into the ore (these threads are not shown in Fig. 4) such as could not possibly have appeared if these pieces of slate had been fragments which had dropped from the cheeks during the formation of a sedimentary deposit. These facts, along with those previously mentioned of a geological nature, are such that Mr. Steavenson's chemical difficulties must give way. What Mr. Steavenson has to do before he is satisfied to believe that the ore was not deposited by a process of replacement, is to show that the facts which he had

brought forward are unreliable, or that the arguments based on them are illogical. It seems necessary to point out to Mr. Steavenson that he has missed the main point in the paper in not seeing that the replacement process is arrived at by a species of induction from *geological* facts, and is altogether independent of *chemical* considerations. As to the manner in which the replacement was effected, and the form of the iron effecting it, he only stated his *opinion*. He agreed with Mr. Steavenson that there is a difficulty in seeing how any solution of iron could replace granite and slate, but he had before him a specimen which came from the Boot deposit, which he thought threw very considerable light on how the replacement might have been effected. A part of this specimen was limestone, and this limestone blended off in one direction into granite, and in the other into hematite. Now, if it were supposed that the hematite of the veins in the granite and slate were preceded by limestone, much of Mr. Steavenson's difficulty would disappear. How the limestone got there is another question which he had not attempted to answer, but it seemed to him that it might have been produced in some such manner as the following. Suppose the rocks to be submerged in the sea, and that heated waters containing carbonate of soda were rising from below through the joints in the rocks, the silica in the walls of these joints would be slowly dissolved. Small quantities of sea water would also find its way into the rocks, and this coming into contact with the ascending alkaline waters, a reaction would ensue between the carbonate of soda and the lime salts in the sea water. The result would be a precipitate of carbonate of lime, which would take the place of the dissolved silica. The other minerals in the rocks might have been previously removed by decomposition through the influence of hydrochloric and carbonic acids. Apart from such considerations as these, however, there is positive evidence that hematite can replace silicious rocks in some way or other, for pseudomorphs of hematite are found after quartz. But even if there was no such evidence, it would be no less certain that the deposits were formed by replacement. What is at present known is not necessarily all that can be known, so that if to-day silicious and aluminous rocks cannot be replaced directly by a solution of iron, it does not follow that they can never be so replaced, much less that such replacement is impossible. But, in view of the fact presented by the piece of limestone from the Nabgill vein in the granite, it is not necessary to suppose that the replacement of the granite and slate by hematite was effected *directly*. The authorities mentioned by Mr. Steavenson as differing from him (Mr. Kendall) also differ from one another.

Mr. Steavenson asks the question: "How was the fact accounted for

that it (red hematite) sometimes took the form of kidney ore, and sometimes that of brown hematite ?" That it sometimes takes the form of kidney ore he (Mr. Kendall) was aware, but he did not know why. He had seen a piece of earthy ore formed inside a locomotive boiler which was partly massive and partly radiated and mammillated, although it had all been subjected to the same external conditions. He had also noticed, in experimenting upon chalk with solutions of perchloride of iron, that the inner surface of the precipitated peroxide of iron—that is where it joined the chalk—had sometimes a mammillated appearance, but not always. The latter part of Mr. Steavenson's question was a puzzle to him, for he had never heard of red hematite (hematite) occurring as brown hematite (limonite). Mr. Steavenson also asked how can the assertion that the ore was "primarily volcanic be reconciled with the transformation theory," or, as he Mr. Kendall preferred to call it, the replacement process. Mr. Steavenson evidently has not felt the force of the word *primarily*. He did not say the *immediate* source of the iron, for obviously that was aqueous, being the solution which acted upon the rocks. He did not see what bearing the quotation from the *Revue Universelle* had upon the question under discussion ; they were not made acquainted with the facts upon which the conclusions therein arrived at were based, so that it was quite impossible for them to form any idea of the validity or invalidity of the conclusions. Mr. Bewick asked him about the Stank deposit, whether it went up into the shale. So far as had yet been proved, he did not think it did. The deposit at Martin occurs at the edge of the limestone adjoining the slate, and the basin in which it lies is mainly in the limestone, but one side of it is formed by slate. At the time Mr. Bewick saw it none of the sides had been reached, and it had all the appearance of being surrounded entirely by drift. It was very much mixed with boulder clay on the upper part of it, and has evidently been much disturbed. A section of this deposit is given in his paper on the hematite deposits of Whitehaven and Furness, already referred to.

That the ore is not directly volcanic, as supposed by Mr. Boyd, he thought he had proved in his paper, and he need hardly go over the ground again, for the shale beds which run through the deposits could never have existed if the ore had been ejected, as a hot boiling mass, from below. He would again refer to Plate XXXI., Fig. 1, where a thin bed of shale was shown running out of the limestone and through a mass of hematite. Now, if igneous matter had been protruded into a cavern, this fragile bridge of shale could hardly have remained there. It might be said, of course, that it was simply an accident that the bed of shale

in the ore corresponded with that in the limestone. But this could hardly be, because, as had been shown in one part of the paper, the ore was not deposited until the carboniferous rocks were tilted, so that if the shale bed in the ore had been deposited at the same time as the ore, although at one or two points there might have been a coincidence between the shale in the ore and some similar bed in the limestone so far as level went, still there would at least have been a want of conformity in them, but that is not so for they are strictly conformable. And then, of course, Mr. Boyd would have the difficulty of explaining the presence in the ore of the organic remains, the absence of any disturbance of the surrounding rocks, and of any calcining effect upon them. He had here a specimen of hematite containing a number of corals; they were very small, but great numbers of them are found in some of the deposits. This brought him to an observation which was made by Mr. Boyd, as to the preference of hematite deposits for limestone. Now this, to his (Mr. Kendall's) mind, was an argument in favour of the explanation which he was bringing forward, because the limestone was much more easily acted upon chemically than any of those silicious or aluminous rocks in which the other deposits occur.

Mr. Marley's suggestion that the inquiry should be divided into two parts—*first*, as to the cause of the hematite ore, *second*, as to the cause of the cavities in which the ore has been deposited—is completely negatived by the sections accompanying the paper, for they show clearly that the ore was *not deposited in cavities at all*, and it is on that conclusion that he Mr. Kendall based his explanation of replacement.

With regard to the so-called vegetable remains mentioned by Mr. Binney, he had, since his paper was published, shown them to Professor Williamson, of Owen's College, who pronounced them not to be plants at all. He might also state that, in addition to the minerals mentioned in the paper as occurring in association with the hematite, he had also found melanterite and turgite, the former at Crowgarth and the latter at Eskett. As to the paper on the North Lancashire deposits, it would give him very great pleasure indeed to supplement the present paper by a similar one on those deposits.

The PRESIDENT said, this had been a most interesting subject, and had raised a very instructive discussion. On the merits of the various theories propounded it was not for him to express any opinion. He must leave the members to draw their own conclusions, and he was sure that all present would unite in thanking Mr. Kendall for his kindness in attending.

The meeting then terminated.

PROCEEDINGS.

ANNUAL GENERAL MEETING, SATURDAY, AUGUST 2, 1879, IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE.

G. C. GREENWELL, Esq., President, in the Chair.

The Secretary read the minutes of the last General Meeting, which were confirmed and signed, and the proceedings of the Council meetings were also read, together with the reports of the Council and of the Finance Committee, which were all agreed to.

The following gentlemen were elected:—

Associate Member—

Mr. Matthew Heckels Douglas, Whitburn Colliery, Sunderland.

Student—

Mr. Samuel Hare, Pemberton Colliery, Wigan.

The following were nominated for election at the next meeting:—

Students—

Mr. Edward Frederic Bell, 13, Old Elvet, Durham.

Mr. Walter Scott, Cornsay Colliery, Lanchester.

Mr. W. O. Baumgartner, East Hetton Colliery, Coxhoe, Co. Durham.

Mr. W. J. S. Todner, Elswick Colliery, Newcastle-on-Tyne.

Mr. J. G. Weeks, Mr. T. Heppell, Mr. J. Cooke, and Mr. C. Z. Bunning were appointed scrutineers to examine the voting papers for the election of officers for the ensuing year.

Mr. James Pease then read the following paper "On a New Method of Rope Haulage."

ON A NEW METHOD OF ROPE HAULAGE.

By JAMES PEASE, M.E.

Since the publication a few years ago of the report by the Tail-rope Committee (appointed by this Institute) on the various systems of rope haulage, this branch of mining detail has received considerable attention, partially as a sequence of that report; but far more, latterly, by reason of the necessity for strict economy, through this present period of unexampled depression in the coal trade; and, as a number of improvements have since been made, and new systems put to work, the selection of the system of haulage which, while it best adapts itself to the difficulties of the situation, is nevertheless cheap and simple to work, now forms one of the leading questions for the mining engineer.

As a preface to this paper it will be advisable to recapitulate the summarised results published by the Committee, with a few remarks on the capabilities of each system then at work, both for the purpose of comparison and as a datum from which to commence this paper.

The tabular statement then put forth was as follows:—

System.	Coals led per day.	Average distance led.	Average gradient. Rise for full tubs.	Horse-power exerted.	Cost of labour per day.	Cost per Ton per Mile.					First Cost.			Costs Ratio.	Working Ratio.
						Ropes or Chains.	Maintaining Plant.	Coals.	Labour.	Total.	First Cost of Wagonway Plant.	First Cost of Engine, Boilers, &c.	Cost per Mile of Wagonway		
	T.	Yds.	1 in.		£ s d.	d.	d.	d.	d.	d.	£	£	£		
Tail-rope	476	2133	213	112·36	1 7 7	·276 (15°/₀)	·462 (24°/₀)	·558 (30°/₀)	·583 (31°/₀)	1·879	3398	1105	723	52	18
Endless-chain	451	1389	59	20·20	0 13 8	·083 (6 °/₀)	·468 (34°/₀)	·256 (19°/₀)	·572 (41°/₀)	1·379	1755	276	941	29	13
No. 1 Endless-rope	384	922	48	62·38	0 17 9	·263 (13°/₀)	·541 (26°/₀)	·237 (12°/₀)	1·020 (49 °/₀)	2·061	1500	553	820	28	20
No. 2 Endless-rope	443	849	36 Fall	29·01	1 10 1	·252 (9 °/₀)	·726 (24°/₀)	·323 (11°/₀)	1·692 (56 °/₀)	2·993	2322	973	893	41	29
Method now described — Surface	†230	750	70 Rise	5	0 4 9	.190	·370	·220	24	1·020	1340	180	....	..	10
Method now described — Underground	†225	350	25	8	0 8 0	·190	·370	·266	·42	1·246	1340	180	850	23	12

* The labour employed, which is only partially utilized, is not averaged on the mile.

† Coals led about one-third of the capacity of the plant.

Although details of four separate systems are here given, two principles govern the whole.

1st.—Train loads at high speed, from six to twenty miles per hour, with intermittent motion and delivery, as illustrated by the tail-rope and endless-rope No. 1.

2nd.—Distributed loads at slow speeds, from one-and-a-half to three miles per hour, with continuous motion and delivery, examples of which are the endless-chain and endless-rope No. 2.

Both of these arrangements appear to have had their origin in part from circumstances which would not only suggest their adoption but materially contribute also to their practical success.

Flat areas of large extent led to the adoption of tail-ropes in the northern and endless-ropes in the midland counties. Strata of a uniform character and inclination, with steep gradients, suggested the use of gravity planes and endless-chain with distributed loads in Yorkshire, Lancashire, and South Wales. The tail-rope being adapted for working undulating roads with branches with a single line of rails, it is necessary to concentrate the traffic at a few points and maintain a high speed (with its consequent liability to accidents), which involves an extra expenditure in horse-power and plant only partially utilized.

ENDLESS-ROPE, No. 1.

The expense of doubling the way is more than compensated by the saving in the other portions of the plant, while it materially reduces the labour charge without any diminution of haulage capacity; should, however, the road be undulating, the saving in labour is not so great, owing to the necessity of locking the tub wheels or coupling up both ends of the set to the rope. Curves can be worked and branches easily managed with this system, riders being required.

Endless-chain is the first example of distributed loads thoroughly carried out; the economy in engines, boilers, and labour, is again large, but the chain being heavy and costly, is evidently adopted in the absence of any simple frictional attachment making ropes available.

The weight of the chain compels its being used over the tub, to the top of which it is attached somewhat awkwardly; this renders it difficult to work with branches or curves.

ENDLESS-ROPE, No. 2.

Instead of being (as no doubt was expected) an economy by substituting a thick heavy rope in place of chain, proved the reverse, outlay and labour being increased to no advantage.

The conclusion of the Committee pointed at the endless-chain as being the most effective and economical system (at that time) in first cost, labour and maintenance, with one or two drawbacks (due to the manner of application), thus practically affirming the principle of slow speeds and distributed loads—a principle sufficiently elastic to meet every condition of roadway.

The attention thus drawn to the system of endless-ropes and chains led to investigations as to how far and under what conditions frictional attachments could be used in combination with light steel ropes in order to dispense with the first heavy charge and superfluous weight of chain and at the same time avoid those drawbacks mentioned in the Committee's report.

Frictional couplings may be of two kinds; 1st, friction by compression of the rope with a lever or screw, either separate or combined, and worked by manual labour; or, 2nd, friction by the deflection of the rope from a straight line actuated by the load itself through the interposition of a lever.

The first kind consists mostly of clamps or levers such as are shown in Plates XXXIX. and XLI., Vol. XVII. These have been modified by the use of screws, but they all more or less damage the rope and require great care from the riders and attendants.

Attempts were made a year or two ago to adapt the "fork" by the addition of a horizontal crank, see A, Fig. 1, Plate XL., with a radius of about five inches used on the top of the tub B, and working by deflecting the rope from a straight line by the action of the load. This was found to answer very successfully for single tubs on level roads, or with flat gradients where very light steel ropes from $\frac{1}{2}$-inch to $\frac{3}{4}$-inch are used, and where boys connect the ropes to the tubs which are self-detached at the respective ends of the plane. Sharp curves or gradients cannot be worked with this system, and branches but imperfectly, owing to both ropes having to be lifted in order to make a connection.

It is found in practice, 1st, that the loading is restricted; 2nd, that considerable side friction is produced by the wheels against the rails; 3rd, that the least defect causes the tub to leave the rails; 4th, that the leverage of the rope above and in front of the empty tub frequently tilts up the rear end against a bad joint in the rails; 5th, that should an undue strain be brought to bear, the rope either bends and slips off the fork or breaks out the tub end.

Another pattern of this fork applied about one-third up the side of the tub is shown in Fig. 2, Plate XL., and is used with heavy iron ropes; this plan does not reduce the side friction against the rails, but there can

be no tilting forward when empty; curves cannot be worked with this fork and branches only by detaching the whole of the empty traffic at each branch in order to connect the full traffic.

An objection common to both these forks is, that should the floor heave, as is common in the midland counties, or the gradients not follow the natural curve of the rope, the tubs are liable to become detached on leaving a falling for a rising gradient.

Having some time ago to lay down a haulage arrangement under the somewhat peculiar conditions shown in Fig. 6, Plate XL., which could not be met satisfactorily by any of the foregoing systems of haulage, the writer succeeded in overcoming all difficulties by adopting a coupling which is shown in Figs. 3, 4, 5, Plate XL.

Instead of producing friction by compression or horizontal deflection it is caused by allowing the hook to hang down like a pendulum free to move through an arc of 20 to 30 degrees, which causes a slight vertical deflection of the rope A, Fig. 7, Plate XL. The clip it will be seen consists of fast and loose jaws (A B, Figs. 4 and 5), $3\frac{1}{2}$ in. in length, suitably bored out for the rope, and loosely clipping it, and being secured by a falling hoop (C), a lad couples it up to the draw bar, the rope being then raised to a suitable height by a small pulley; he then places the rope in the space D and allows the hoop to drop; the clips are then at once seized by the weight of the load whilst the tub is being set in motion. The clip is disengaged automatically at the ends of the plane by a pair of slides which raise the ring C and disengage the clip. (See Fig. 7.)

The rope being carried beneath the tub enables the sharp curve at A, Fig. 6, to be met in a comparatively easy manner, the friction being divided over six small steel sheaves which pass the clip very smoothly. With this system no rollers are necessary to support the rope, the tubs being placed 15 yards apart being sufficient to do so.

This system is found in working to be remarkably free from accident, the rope acting like a third rail, making it difficult for the tubs to leave the road unless they be absolutely displaced.

With the load properly distributed the horse power required with this system is very small.

The rope is driven by ordinary V driving wheels. The V, with an angle of about 28 degrees, and one turn of rope, gives the requisite friction.

The estimated maintenance charges are :—Ropes, to be replaced every four years; driving wheels to be turned up every two years; and the necessary casual repairs to engine, tubs, and clips.

To illustrate Mr. James Pease's paper on "A new method of Rope Haulage"

Vol. XVIII Plate XL.

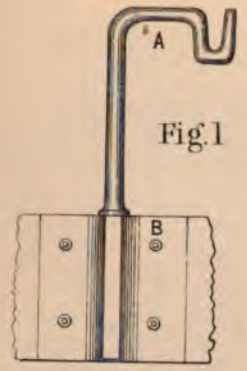


Fig. 1

Fig. 3

Fig. 4.

Fig. 5

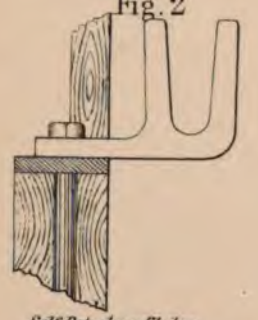


Fig. 2

Fig. 6

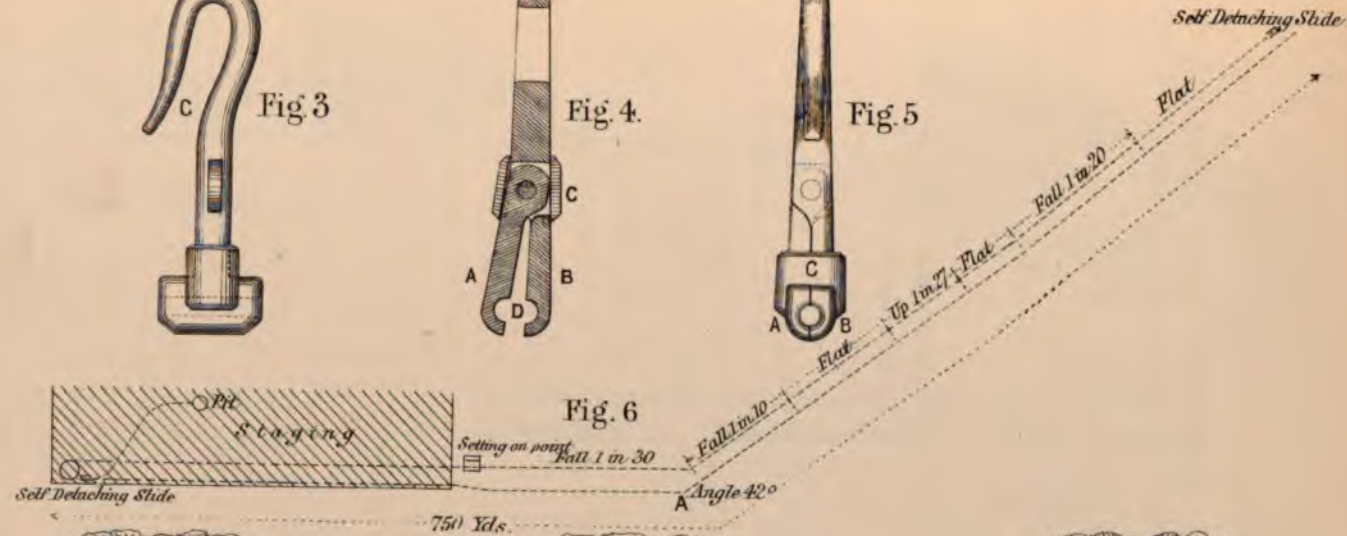


Fig. 7.

Proceedings N.E.I. of M.M.E. 1875-76

To illustrate Mr. W. Jackson's paper on "Endless Rope Haulage."

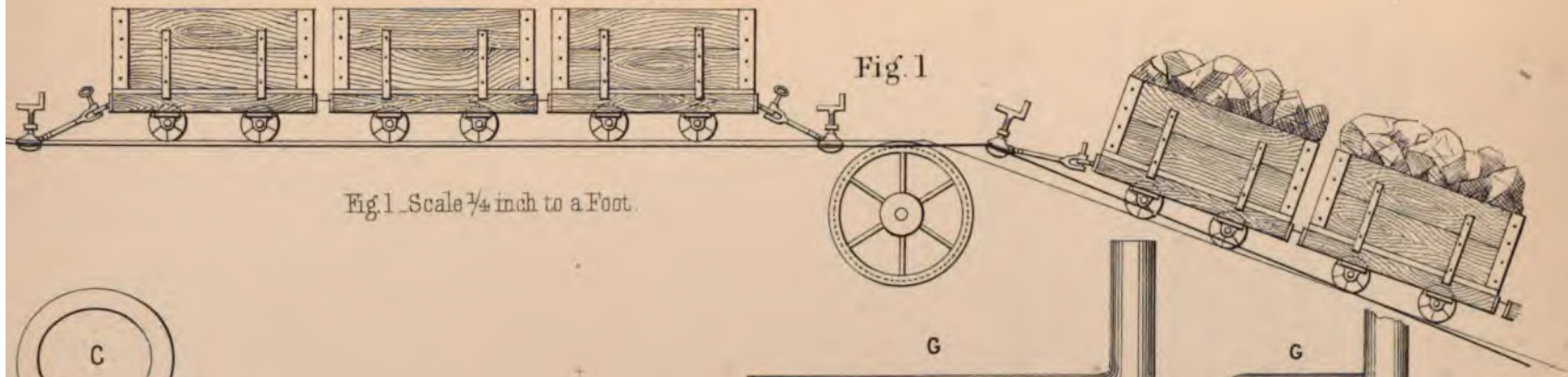


Fig. 1

Fig. 1. Scale ¼ inch to a Foot.

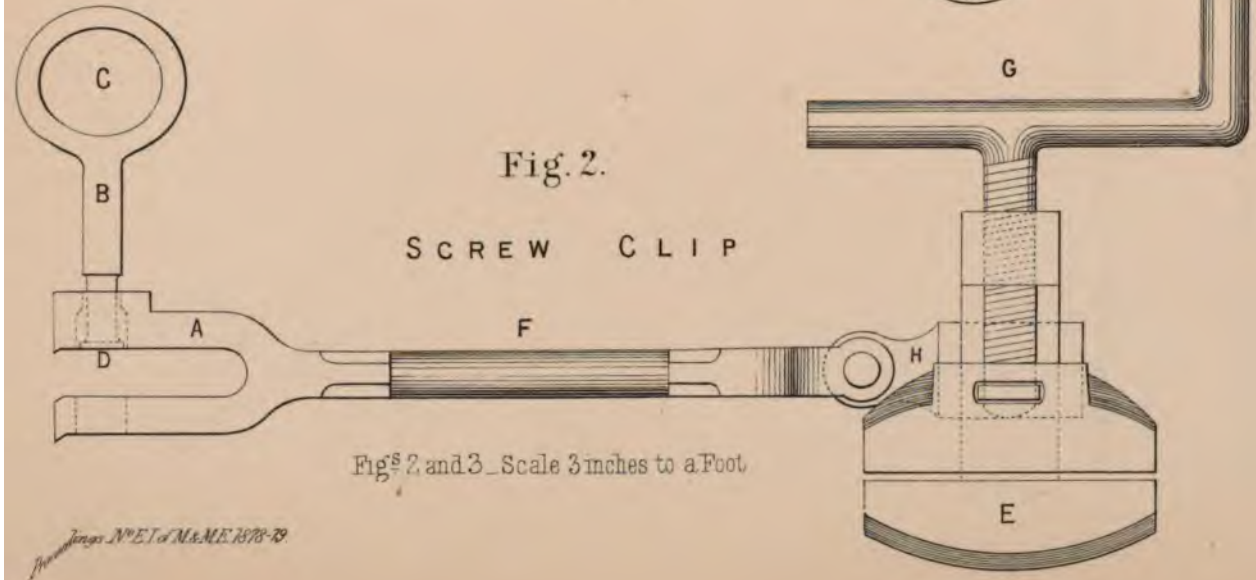


Fig. 2.

SCREW CLIP

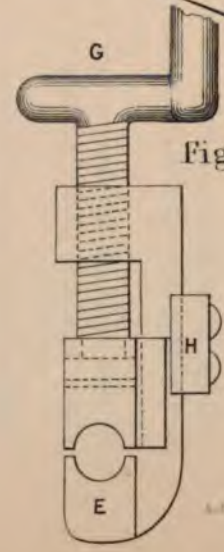


Fig. 3

Figs. 2. and 3. Scale 3 inches to a Foot.

Proceedings No. 1 of M.&M.E. 1878-79.

The daily labour charge on the surface tramway is 4s. 9d. for 230 tons, but the way being only partially utilized, 600 tons per day might be carried without any addition to the expense.

With underground-road man and two branches the labour is 8s. for 225 tons, and a similar increase of quantity without additional expense could be maintained here.

This system is at work in two large collieries both above and below ground, and is being substituted in place of the forks in Figs. 1 and 2. Trials are also being made with it at several collieries with a view to its adoption.

Mr. W. JACKSON then read the following paper, "Some Remarks on Endless-rope Haulage."

SOME REMARKS ON ENDLESS-ROPE HAULAGE.

By W. JACKSON.

The writer having had considerable experience with the endless-rope system of haulage, ventures to explain an arrangement which may compare favourably in its results with many other systems of running endless-ropes, and attaching and detaching tubs at their various stations, so that the shock of putting the load in motion from a state of rest may be as much as possible avoided.

The several methods of attaching and detaching tubs to and from the endless-rope, which are shown in Figs. 1, 2, and 3, Plate XL., do not fully carry out this desideratum, the importance of which becomes apparent when it is considered that a dead weight, say, for instance, a number of tubs containing perhaps five tons of coal in a state of rest is required to be put in motion instantaneously at a speed equal to four miles per hour, for if the attachment is so constructed that it will not yield or give while the connections have to be made, the shock will be so great as to seriously damage the clips, tubs, rope, and machinery generally, if not to cause actual breakage.

The methods shown in Figs. 1 and 2, Plate XL., for instance, clutch the rope firmly by twisting the lever round the moment the tub is put into motion, which subjects the whole of the machinery to a severe strain unless the speed be slow and the load light. Besides which it requires the rope to run over the tubs, which the writer does not consider the most advantageous arrangement.

The method shown in Figs. 3, 4, and 5, Plate XL., called a vertical clip, in the writer's opinion, with regard to its utility, may be classed with the method just described; that is to say, in its application there is no provision made for setting a heavy weight from a state of rest to a state of motion in the shortest possible time without giving an undue strain. The hook-end of this clip is first attached to the ring at the end of the draw-bar on the tub; a box which slides up or down in the middle of the clip is

then raised or lifted up to allow the tong end of the clip to open, the rope is then admitted between the tongs and the box allowed to drop, the result being, that even with a moderate load and a moderate speed, in consequence of the leverage being so great, a portion of the rope is twisted into an almost vertical position, which prevents any yielding or slipping of the rope through the clip, such slipping being so desirable if the load is to be started without undue strain, comparative safety, and freedom from accident. Another objection may be urged against this clip, viz., that it cannot be conveniently made much shorter than is shown in the Plate, say eight or nine inches long, and with tubs having wheels ten inches in diameter, it will be observed that the draw-bar ring will hang down to within four to five inches of the rope. To connect the draw-bar ring to the rope when in motion, with a vertical clip eight inches long, must be inconvenient if not dangerous; and to remove the draw-bar itself from its usual place underneath the tub and fix it above the sole-bars, so as to give sufficient height to allow of the use of the vertical clip, would entail a very large expense even supposing the cost of removal to be only a few shillings per tub. This clip is self-detaching, but it appeared to the writer whilst watching it at work, to be uncertain in its action. The way the self-detachment is accomplished is by means of two pieces of angle iron laid down parallel with each other on a slight inclination, and placed sufficiently apart to admit the lower part of the clip, whilst the ring C coming in contact with the edges of an angle iron, is caused to slide up the clip, and so relieve it from the rope; but the clip still hangs to the tub, and has to be removed, so that it is questionable if the same person that removes the clip from its position after it has disconnected itself, could not, at the same time, disconnect the clip from the rope; thus the disconnecting arrangement, except under certain conditions, does not possess any material advantage. It has also been stated that these clips do not require rollers for the rope to trail on; in such a case a clip is required for every tub, and the tubs placed at equal distances apart, or some portion of the rope will be sure to trail. The question therefore arises, would it not be cheaper to have rollers rather than an extra quantity of clips? These considerations induced the writer to design a screw clip which has been working most satisfactorily during the last seven years, during which time a fair opportunity has been afforded of judging as to its practical utility, and it can be said with confidence that it does the work required expeditiously, safely, and economically. Expeditiously, because it can be easily connected or disconnected; safely, because it will, no matter the speed of the rope, how heavy the load, or how steep the gradient, start the journey of loaded tubs

in motion without the slightest shock or impact; economically, because it does not, to any appreciable extent, wear the rope, as compared to the enormous amount of work it is capable of performing.

In applying the screw clip, the end A (Fig. 2, Plate XLI.) of the connecting rod is attached to the ring in the draw-bar. The pin B, with the handle C, is lifted up to the top half of jaw, but, in order to prevent its being drawn out and getting lost, a projection, D, at the bottom of the pin prevents it from passing through the top of jaw. The draw-bar ring is now placed between the jaws, and the pin allowed to drop through the draw-bar ring and lower jaw. It will be noticed that this jaw and ring are sufficiently loose to allow the clip to move at any angle on either side of the tubs, thus enabling it to pass around any pulleys it may have been necessary to place on the engine plane to suit the curves. The person who has just connected the set of tubs now places the clip E on the rope, screwing the clip gently down by means of a few turns of the handle G. This clip is attached to the link F by the joint H, secured to the upper part of E. The moment the clip commences to grip the rope, the set of tubs moves but slowly, the difference between the speed of rope and tubs being regulated at will by the attendant at the screw; but when the set of tubs acquires the same speed as the rope, the attendant gives the clip a final screw up, and the set of tubs passes on to the out-bye end.

At any desired distance a lever is placed (actuated by the tubs in passing), which rings a bell as a signal for the next set to be connected. This is not essential to the use of the clip, but is added for the sake of regularity.

When detaching at the out-bye end it is only necessary to give the screw G a few turns, and release the pin from the draw-bar ring by drawing the pin straight up. The tubs, being disconnected from rope and clip, run by their own gravity to the pit bottom.

For undulating planes or steep gradients, one clip before and one behind the set will be required (see Fig. 1); and in such a case it is usual to send twice the number of empties in-bye as full ones out-bye. This will regulate the number of clips required.

Fifteen of these screw clips, viz., ten with full and five with empty tubs, are sufficient to haul 1,000 tons of coal up an incline of an average gradient of 1 in 20, with a maximum gradient of 1 in 14, 1,000 yards long in eight hours, working at a speed of from three to four miles per hour, at a cost which it is believed would compare favourably with many other systems of haulage placed or working under similar circumstances

To show the improvement effected by this method of attaching tubs with the old method of run riders, the extra cost for wages alone to haul the quantity above mentioned would amount to something like £600 per year.

The writer wishes it to be understood that he believes that the other methods before referred to may perform their work satisfactorily under the conditions of light loads, level planes, and slow speed. The screw clip can however be worked equally well under such conditions, while it can be used with advantage under circumstances where it would be practically impossible to work with the others. The screw clip itself costs rather more, and, although it is more expensive, yet when it is considered that it will do six times the amount of work such cost becomes immaterial.

Mr. D. P. MORISON then read "An Introductory Notice on Boiler Accidents and their Prevention."

INTRODUCTORY NOTES ON BOILER ACCIDENTS AND THEIR PREVENTION.

By D. P. MORISON.

I.—EFFICIENT INSPECTION.

In compiling these notes merely as the introduction of so important a subject, the writer has had mainly in view the daily increasing interest displayed by the Legislature, the public, and, above all, by those personally and practically responsible for the safety of life, limb, and property, in those branches of their industries where steam boilers are a necessity. It has also been his endeavour to explain fairly and impartially the different modes of gaining such safety, and of recording the results so obtained.

The attention of Parliament has been largely bestowed upon the subject of boiler registration and inspection; and this last session the matter was again under their consideration and will probably be one of the prominent topics of the next; and seeing this, the writer deemed that a treatise on boiler accidents and their prevention would be a topic worthy of the notice of the members of an institution which has recently been favoured by the Government, and whose Transactions have so long and so justly been held in esteem by all interested in the saving of life among those engaged in mechanical employments. The fact of *mechanical* engineers of the district forming now so important a section of our body renders the benefits to be derived by discussing such a paper in all its bearings still more fully apparent.

The number of boilers in the United Kingdom in the past year was estimated by the most competent authorities at 200,000; although this certainly appears to the writer from his own observation to be an understatement; taking into account the various localities and interests represented by the large number (nearly one thousand) of the members, it may safely be assumed that one-fourth at least of those boilers must, more or less, come under their notice, and this fact should of itself be sufficient to elicit some valuable practicable notes from such extensive experience as this would indicate. The present portion of the paper is

intended, as before said, merely as an introduction, and therefore will simply be a means of condensing the classification of those branches of the subject which may be included under the denomination of "efficient inspection," viz.:—

1.—The necessity of efficient inspection.
2.—What is efficient inspection?
3.—The means of obtaining efficient inspection.

1.—THE NECESSITY OF EFFICIENT INSPECTION is so apparent as to require little or no comment; but in practice it is to be feared it is a point often neglected, either from a sense of security engendered by the consciousness of good material and careful usage, or from partial or total ignorance of the many dangers which are compassed in steam generators and their appurtenances. Boilers doubtless have exploded under what was intended to be careful inspection, but at the same time it is now generally considered as the best means of preventing explosion.

Even if other precautions are taken, such as extremely good materials and workmanship, low pressure in proportion to the strength of the boiler, ample safety valves, hydraulic tests, and care in working, periodical inspection still remains an additional and a most important safeguard.

It may safely be further inferred that all faults leading to explosion are not always detected by the fact of the occurrence of explosions of boilers belonging to the Government, both ashore and afloat, where every care is considered to be taken in every detail.

That boilers may be worked in great numbers without explosion in consequence of careful inspection may be inferred from the lessened number of explosions among the boilers enrolled under the various associations both official and private. As, however, there are a great number of boilers under no inspection at all, or rejected by the associations as not up to their standard, and in many cases the inspection at the command of private establishments is not sufficient, explosions still continue much as usual as regards the annual number, and although forming a small percentage of accidents and deaths as compared with other disasters, such as accidents on railways, at sea, or in the streets, attention is much directed to the subject, and it is incumbent on engineers to find a remedy if possible to mitigate their severity.

From records of 1,475 boiler explosions in the United Kingdom, killing 2,184 persons and injuring 3,102 others, those of the last ten years may suffice for the present purpose:—

Year.	No. of Boilers.			No. of Persons.		No. of Persons.
1869 ...	59	Exploded	Boilers, killing	87	and injuring	128
1870 ...	70	do.	do.	85	do.	138
1871 ...	66	do.	do.	66	do.	113
1872 ...	74	do.	do.	50	do.	137
1873 ...	88	do.	do.	66	do.	94
1874 ...	76	do.	do.	77	do.	198
1875 ...	68	do.	do.	81	do.	142
1876 ...	39	do.	do.	93	do.	110
1877 ...	44	do.	do.	54	do.	75
1878 ...	46	do.	do.	47	do.	84
	630			706		1,219

In further illustraton of the figures obtained by compilation of records of explosions, the annexed tables are extracted from a publication by Mr. E. B. Marten, Ass. C.E., Table I. being a summary of records, and Table II. a summary of causes of explosion (these will be supplemented by later statistics in subsequent notes):—

TABLE I.

SUMMARY OF RECORDS OF STEAM BOILER EXPLOSIONS UP TO 30TH JUNE, 1870, SHEWING DESCRIPTION OF EXPLODED BOILERS.

DESCRIPTION OF BOILER.	Explosions up to June, 1866.			Explosions in the Four Years from June, 1866, to June, 1870.			TOTAL EXPLOSIONS UP TO JUNE, 1870.		
	English	Foreign	TOTAL.	English	Foreign	TOTAL.	English	Foreign	TOTAL.
Marine	57	263	320	12	64	76	69	327	396
Cornish, Lancashire, or other with internal flues ...	140	1	141	84	3	87	224	4	228
Locomotive	91	29	120	10	68	78	101	97	198
Plain cylindrical, externally fired	114	2	116	54	3	57	168	5	173
Balloon, haystack, wagon, Butterley, British tube, elephant, or Trevistick	62	2	64	5	2	7	67	4	71
Portable, agricultural, upright, crane, or very small	28	1	29	17	17	34	45	18	63
Heating kitchen, domestic, Ray, steamers, etc. ...	14	...	14	22	14	36	36	14	50
Furnace, upright	10	...	10	8	...	8	18	...	18
Not sufficiently described to be classified	203	29	232	7	175	182	210	204	414
TOTALS	719	327	1046	219	346	565	938	673	1611

TABLE II.

SUMMARY OF CAUSES OF THE STEAM BOILER EXPLOSIONS FOR THE FOUR YEARS ENDING 30TH JUNE, 1870, IN GREAT BRITAIN.

CAUSES OF EXPLOSION.	Number of Explosions.	Number of Persons Killed.	Number of Persons Injured.
(a.)—Faults in construction or repair ...	95	128	167
(b.)—Faults which should be detected by periodical examination ...	62	105	185
(c.)—Faults which should be prevented by careful attendants	54	79	84
(d.)—Extraneous or uncertain causes ...	8	3	14
TOTALS	219	315	450

It is evident that a large proportion of those accidents classified under the initials *b* and *c* might have been averted by the additional safety resulting from efficient inspection.

This leads to the second division of our subject :—

2.—WHAT IS EFFICIENT INSPECTION?—So much diversity of opinion prevails as to the best means of obtaining efficient inspection that the actual duty itself is often overlooked.

It may be described as intimate acquaintance with the boiler in its entirety, in its materials, in its construction, in its workmanship, in its setting, in its management, and in its general constitution; or, as the French term it with much appropriateness, *tempérament*.

It should be thoroughly independent of those in daily charge of it, and as frequent and complete as possible. The greatest strength of a chain is its weakest link, and so the strength of a boiler as a whole depends often upon the weakness of a very infinitesimal portion of its many points which might easily escape any observation but that of a special and trained man.

The recognised associations on the Continent have all special rules approved by their Governments tending to prove the urgent necessity for intimate and detailed knowledge of the internal temperament of a boiler. The following being brief but to the point may be cited :—

Explosions in boilers occur (1) from natural deterioration of materials, (2) from defects of construction, and (3) from incapacity of those in charge.

They principally are due to defects unobserved from the reason that no pains have been taken with their examination. Examination or inspection is often neglected or postponed on account of the cost of inspection.

Defective materials and bad workmanship frequently occur in all classes of boilers.

Low price often takes priority over quality.

Testing by the hydraulic press is not sufficient to indicate practical weakness or defects.

The internal examination of boilers is the only reliable mode of ascertaining their condition. When this examination is carefully effected it usually affords the means of ascertaining the safety of the boiler.

Every separate part of a boiler should be carefully examined, because each one may lead to danger.

The gist of good inspection was most lucidly given in a paper read before the Institute of Engineers in Scotland as a communication by Mr. J. G. Lawrie, part of which, now extracted, will point to the details of requisite inspection.

To insure due attention a written report should be made, which must be perfectly intelligible to any one who has not seen the boiler; and, to prevent confusion, no two boilers should be mentioned on one paper; and the report should be made complete at once, and illustrated with sketches, so as not to need fair copying. In the first place, every particular of boiler and fittings, and settings, should be noted that can be seen from the outside of the boiler, with sketches and sufficient dimensions to make complete detailed drawing if required.

The boiler should then be entered, and internal sketch and dimensions taken sufficient to make complete drawing. The plates should then be felt in every part with a light hammer, and the general condition noted.

The flues should be reserved for the last, because they are generally dirty, but this is often the most important part of the inspection. The fire grate and each flue should be entered and traversed, and every part of the boiler plate felt with a hammer, and also dimensions taken as before.

This is not all that is necessary to obtain complete information, for there still remains those parts of the boiler in contact with the brickwork, and the neglect which often leads to disaster. It is easy to clear the brickwork sufficiently for examination, but a little arrangement when setting the boilers would make it far easier.

It may be well to mention some of the chief impediments to carrying out this inspection. It is often impossible to make even the external examination, because boilers are so smothered up with brick and stonework. The clothing of boilers is often justly urged as leading to economy

of fuel, but it should not be done in such a way as to preclude examination. The most rapid corrosion goes on if a leak should take place beneath the covering, especially if it consists partly of sand or ashes.

Internal examination is sometimes prevented by too small a manhole, or one so awkwardly placed as to make it almost impossible to get into the boiler; but the most usual difficulty is the want of room to move about, or to use a hammer. Sometimes, also, there is no means of cooling sufficiently to allow of a person remaining in the boiler for many minutes.

Each form of boiler has its peculiar difficulty. The Cornish or one-tube boiler is one of the most awkward, as there is so little space between the tube and shell at the sides and bottom, and a false step may cause the inspector to slip and become wedged.

The Lancashire double-flue, or two-tube boiler, obviates this difficulty, but involves another manhole to get at the space beneath the tubes.

Most of the multitubular boilers, such as the locomotives, are too small to enter, and the impossibility of internal examination has led to many explosions. Of course the difficulty of examination is much increased if the scale is not well cleaned off, as without this many faults will be overlooked.

The easiest boilers to examine internally are the plain cylinders and others without internal tubes, and this facility for examination is one of their chief recommendations.

3.—Means of obtaining Efficient Inspection. — Having now briefly explained the necessity and the constitution of efficient inspection, it remains for the writer to allude to the various methods in actual use, or merely *in embryo* for obtaining this efficiency. These may be divided into groups which may for succinctness sake be denominated—

(a.)—Private firm inspection.
(b.)—Association of firms (home).
(c.)—Association of firms (foreign).
(d.)—Inspection companies.
(e.)—Inspection and assurance companies.
(f.)—(In contemplation or under advice a system by which the Government shall have directly under its own control the registration and inspection of all boilers either by specially appointed officials or by some mode of incorporating the present methods.) This we may name *Government inspection.*

Extent of inspection by various societies at home and abroad :—

NUMBER OF BOILERS INSPECTED IN THE UNITED KINGDOM.

Steam Users	3,500
Steam Power	23,000
National	7,200
Midland	3,218
Yorkshire	2,000
Mutual	1,000
London Mutual	1,000
Newcastle	114
Engine and Boiler	500
English and Scotch	?
	41,532

All the above compete as private ventures, as there is no compulsion; the same as steam shipowners, who are not obliged to have Board of Trade inspectors, but do so to save themselves from blame in case of accident.

NUMBER OF FOREIGN BOILERS INSPECTED.

1.—Hanover,	according to	Report to	1876,	Inspected	525	Boilers.
2.—Bremen	do.	do.	1878,	do.	414	do.
3.—Halle	do.	do.	1877,	do.	423	do.
4.—Breslau	do.	do.	1878,	do.	612	do.
5.—Offenbach	do.	do.	1878,	do.	546	do.
6.—Brunello	do.	do.	1877,	do.	1,740	do.
7.—Hamburg	do.	do.	1878,	do.	662	do.
8.—Mannheim	do.	do.	1877,	do.	1,072	do.
9.—Munchen	do.	do.	1878,	do.	1,422	do.
10.—M. Gladbach	do.	do.	1876,	do.	363	do.
11.—Magdeburg	do.	do.	1878,	do.	1,338	do.
12.—Mulhouse	do.	do.	1877,	do.	1,470	do.
13.—Aachen	do.	do.	1878,	do.	356	do.
14.—Bernberg	do.	do.	1877,	do.	640	do.
15.—Frankfort	do.	do.	1878,	do.	476	do.
16.—Kaiserslawtern	do.	do.	1875,	do.	574	do.
17.—Siegen	do.	do.	1878,	do.	423	do.
18.—Wien	do.	do.	1876,	do.	2,952	do.
19.—Luzern	do.	do.	1878,	do.	1,275	do.
20.—Saarbruck	do.	do.	1878,	do.	542	do.
21.—Paris	do.	do.	1877,	do.	200	do.
22.—Lyons	do.	do.	1878,	do.	271	do.
23.—Lille	do.	do.	1876,	do.	?	
24.—Chemnitz	do.	do.	1878,	do.	258	do.
25.—Rouen	do.	do.	1877,	do.	?	
26.—Neuwied	do.	do.	1876,	do.	355	do.
					18,909	

Say 20,000.

None of these foreign societies compete, but each has a district, and all boilers are by law to be inspected by them.

The rules, regulations, and constitutions of a few of these societies will be embodied in subsequent remarks, as well as the advantage which has been derived from their assistance in independent inspection.

The general conclusion from the consideration of this introductory portion of the subject is, that the best means of preventing boiler explosions is to use boilers which may be safely classified as *good*, and have them carefully inspected in every part at least once in six months, so as to detect evils which might lead to a rupture or collapse. It would be a great safeguard if all persons in charge of boilers were competent to thus inspect them and the doing so were made part of their regular duty. As inspection has so often been urged as essential to safety, it is no matter of surprise that it has attracted the attention of Government. A Special Committee sat for many days and took evidence during the last two sessions; but after very careful consideration they did not recommend Government inspection, lest it should remove responsibility from the owners, who should be the best judges of the fitness of inspectors, as they are the natural guardians of their own boilers.

This decision was not arrived at hastily, as many witnesses were examined, and the statistics and experience gathered by the Steam Users, the Steam Power, the National, and the Midland Boiler Associations, beside the opinion of many eminent engineers and manufacturers, were fully weighed. The importance of the loss of an average of 75 lives from about fifty explosions, or one boiler in every 4,000 per annum, was not lost sight of, nor the value of periodical competent inspection, as carried out by the voluntary associations; but it was feared that any system of compulsory inspection, although it might be under the management of a kind of Steam Parliament composed of representatives of the public, or others elected by those who own or work steam boilers, could only be accomplished at an unwarrantable cost, while it would indirectly tend to the adoption only of certain supposed types of boilers and engines and modes of working, and thus impede progress and improvement in the face of present increasing foreign competition in that which is the very mainspring of national prosperity.

It is not improbable, however, that the Legislature may see fit to give to those injured, or to the friends of those killed by boiler explosions, greater facilities for obtaining compensation in order to induce the greatest possible care on the part of all who use steam power.

It may also be found practicable to empower coroners, or some other

competent authorities, to obtain and publish trustworthy reports of all cases of boiler explosions, whether fatal or not, so as to enable those using boilers, and especially the men in charge, to profit from the experience of others.

The main part of the concluding remarks has been derived from an article in the "Mining Magazine," by Mr. E. B. Marten, in the year 1872, and the writer has adopted these views as a fit termination to the present introductory notes, which, as before explained, he trusts may, as well as his subsequent remarks on the same subject, pave the way for many instructive and practical additions from members of this Institute.

Mr. J. A. RAMSAY then read a paper "On Fuel, particularly Brown Coal, in its Formation and as an Article of Commerce," which will be published in a subsequent Part of the Transactions.

APPENDIX.

BAROMETER AND THERMOMETER READINGS FOR 1878.

By the SECRETARY.

These readings have been obtained from the observatories of Kew and Glasgow, and will give a very fair idea of the variations of temperature and atmospheric pressure in the intervening country, in which most of the mining operations in this country are carried on.

The Kew barometer is 34 feet, and the Glasgow barometer 180 feet above the sea level. The latter readings have been reduced to 32 feet above the sea level, by the addition of ·150 of an inch to each reading, and both readings are reduced to 32° Fahrenheit.

The fatal accidents have been obtained from the Inspector's reports, and are printed across the lines, showing the various readings. The name of the colliery at which the explosion took place is given first, then the number of deaths, followed by the district in which it happened.

At the request of the Council the exact readings at both Kew and Glasgow have been published in figures.

BAROMETER READINGS, &c.

MAY, 1878.

	KEW.						GLASGOW.					
	Barometer.				Temperature.		Barometer.				Temperature.	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.
1	29·573	29·599	29·573	29·682	67·8	52·5	1	29·534	29·566	29·568	29·637	64·8	43·2
2	29·759	29·864	29·882	29·970	67·3	48·8	2	29·662	29·708	29·707	29·785	58·1	47·5
3	29·972	30·001	29·969	29·999	64·1	52·2	3	29·813	29·819	29·771	29·737	58·8	43·5
4	30·033	30·067	30·056	30·090	62·0	45·6	4	29·746	29·817	29·880	29·942	56·1	45·3
5	30·079	30·036	29·928	29·877	64·9	42·1	5	29·934	29·944	29·874	29·850	66·4	45·1
6	29·744	29·686	29·610	29·609	66·1	49·0	6	29·794	29·732	29·611	29·592	63·9	48·5
7	29·612	29·664	29·612	29·612	66·8	55·3	7	29·591	29·692	29·725	29·747	52·2	46·0
8	29·576	29·594	29·650	29·740	58·5	47·0	8	29·749	29·815	29·862	29·928	49·7	44·0
9	29·750	29·810	29·820	29·860	65·8	47·1	9	29·933	29·919	29·888	29·915	53·5	41·1
10	29·800	29·771	29·716	29·690	71·2	50·2	10	29·694	29·848	29·759	29·742	55·8	37·2
11	29·579	29·544	29·628	29·678	66·7	50·9	11	29·694	29·613	29·522	29·542	51·3	45·0
12	29·658	29·656	29 619	29·587	70·8	49·5	12	29·528	29·534	29·501	29·500	65·4	45·8
13	29·491	29·552	29·536	29·553	62·3	51·8	13	29·445	29·367	29·318	29·315	59·4	51·5
14	29·483	29·455	29·463	29·559	62·3	51·0	14	29·253	29·214	29·163	29·175	61·2	50·2
15	29·514	29·448	29·481	29·560	61·0	52·6	15	29·193	29·149	29·071	29·211	56·4	50·1
16	29·684	29·807	29·817	29·772	61·9	50·0	16	29·329	29·502	29·459	29·279	60·4	48·0
17	29·775	29·881	29·996	30·042	66·8	57·0	17	29 271	29·366	29·645	29·787	59·8	50·7
18	29·884	29·804	29·837	29·903	69·1	52·0	18	29 731	29·539	29·488	29·506	63·2	48 7
19	29·833	29·848	29·805	29·852	61·0	51·8	19	29·450	29·363	29·362	29·530	56·9	47·7
20	29·866	29·834	29·752	29·795	56·9	43·8	20	29·612	29·705	29·749	29·731	50·1	40·5
21	29·881	29·887	29 858	29·905	55·2	39·1	21	29·641	29·647	29·666	29·701	50·0	36·5
22	29·908	29·937	29·905	29·830	58·0	41·9	22	29·751	29·755	29·717	29·655	54·9	42·5
23	29·639	29·428	29·322	29·340	61·0	46·9	23	29·511	29·390	29·331	29·327	53·3	44·9
24	29·312	29·278	29·255	29·356	59·6	49·0	24	29·327	29·367	29·391	29·440	53·2	45·3
25	29·512	29·634	29·671	29·747	59·0	45·0	25	29·445	29·496	29·508	29·557	57·9	39·3
26	29·737	29·771	29·765	29·796	60·4	45·0	26	29·562	29·364	29·554	29·385	57·4	40·5
27	29·776	29·774	29·748	29·791	62·1	47·0	27	29 580	29·526	29·649	29·727	57·4	44 3
28	29·770	29·773	29·725	29·796	62·7	45·0	28	29·765	29 839	29·886	29·974	59·3	44·7
29	29·772	29·914	30·010	30·113	56·7	49·2	29	30·025	30·093	30·091	30·116	61·9	46·7
30	30·113	30·128	30·084	30·063	55·0	42·0	30	30·096	30·062	30·026	30·028	63·0	42·7
31	30·028	29·998	29·928	29·922	63·1	39·7	31	30·013	29·986	29·934	29·965	64·1	46·1

JUNE, 1878.

1	29·933	29·992	30·010	30·031	56·4	45·1	1	29·992	29·998	29·958	29·948	60·4	42·8
2	30·021	30·015	29·961	29·934	63·1	44·0	2	29·954	29·941	29·900	29·903	58·3	45·3
3	29·884	29·915	29·894	29·877	67·2	51·0	3	29·876	29·909	29·896	29·878	54·4	45·2
4	29·794	29·750	29·737	29·795	64·3	52·1	4	29·820	29·792	29·806	29·886	52·9	42·4
5	29·880	30·033	30·094	30·136	57·8	47·5	5	29·946	29·994	30·005	30·043	60·1	40·8
6	.....	30·200	30·179	30·191	67·4	46·1	6	30·075	30·127	30·088	30·078	59·2	42·0
7	.....	30·152	30·047	29·981	68·0	50·5	7	30·002	29·914	29·862	29·814	59·4	46·0
8	.....	29·749	29·627	29·605	70·2	53·7	8	29·665	29·614	29·473	29·331	61·3	53·1
9	29·618	29 595	29·516	29·543	65·1	54·6	9	29·305	29·352	29·313	29·327	64·3	50·1
10	29·644	29·726	29·756	29·800	64·7	52·3	10	29·327	29·372	29·453	29·533	63·0	50·4
11	29·701	29·575	29·445	29·523	63·0	51·4	11	29·517	29·407	29·468	29·222	57·0	47·9
12	29·559	29·555	29·566	29·706	64·0	50·0	12	29·248	29·374	29·522	29·664	57·0	50·0
13	29·767	29·820	29·796	29·832	66·6	51·7	13	29·746	29·814	29·831	29·920	60·2	47·3
14	29·832	29·864	29·856	29·871	56·7	49·0	14	29·923	29·933	29·868	29·862	57·0	47·7
15	29·856	29·857	29·831	29·828	59·8	44·9	15	29·820	29·802	29·753	29·791	60·8	48·2
16	29·793	29·795	29·753	29·780	62·1	50·0	16	29·809	29·799	29·769	29·786	66·0	44·7
17	29·774	29·825	29·820	29·859	64·8	49·0	17	29·737	29·740	29·751	29·779	62·9	47·8
18	29·856	29·877	29·865	29·893	65·0	51·0	18	29·765	29·974	29·772	29·818	63·6	48·7
19	29·893	29·933	29·944	30·002	66·2	49·4	19	29·848	29·902	29·912	29·972	64·9	47·4
20	30·017	30·033	30·015	30·062	71·2	47·5	20	29·962	29·940	29·877	29·890	69·0	47·9
21	30·083	30·097	30·090	30·130	73·7	46·4	21	29·827	29·915	29·975	30·055	64·8	52·7
22	30·157	30·164	30·111	30·109	76·6	50·0	22	30·083	30·095	30·040	30·033	69·6	49·0
23	30·082	30·062	30·026	30·029	78·5	56·8	23	30·008	29·996	29·982	29·952	66·2	48·3
24	30·033	30·061	30·046	30·096	80·5	57·9	24	29·916	29·946	29·967	29·992	64·0	56·9
25	30·106	30·156	30·134	30·160	82·1	61·4	25	30·000	30·045	30·048	30·062	72·0	58·1
26	30·150	30·154	30·108	30·134	85·1	57·5	26	30·062	30·070	30·055	30·078	77·7	54·6
27	30·090	30·068	29·986	29·962	83·9	63·6	27	30·041	29·986	29·928	29·940	85·0	68·4
28	29·900	29·896	29·871	29 872	79·9	63·4	28	29·952	29·906	29·963	30·023	81·1	56·2
29	29·835	29·814	29·758	29·755	77·7	58·2	29	30·035	29·993	29·911	29·915	73·0	54·5
30	29·722	29·756	29·710	29·864	70·3	55·0	30	29·909	29·915	29·897	29·963	71·2	54·5

BAROMETER READINGS, &c.

JULY, 1878.

	KEW.						GLASGOW.					
	Barometer.				Temperature.		Barometer.				Temperature.	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.
1	29·883	29·897	29·866	29·845	67·0	54·3	29·946	29·940	29·915	29·943	64·6	52·8
2	29·828	29·837	29·812	29·862	62·0	53·0	29·916	29·901	29·857	29·855	63·5	51·0
3	29·865	29·903	29·938	30·067	61·3	52·4	29·848	29·906	29·926	29·990	67·9	50·3
4	30·101	30·126	30·089	30·110	69·9	47·1	29·988	29·974	29·928	29·842	59·3	48·9
5	30·098	30·090	30·064	30·046	70·1	54·6	29·804	29·814	29·762	29·730	63·3	58·2
6	29·987	29·976	29·948	29·981	74·8	58·1	29·734	29·767	29·798	29·835	65·3	55·8
7	29·969	29·973	29·950	29·960	72·1	55·4	29·820	29·842	29·867	29·928	66·8	53·9
8	29·984	30·051	30·089	30·126	68·8	56·2	29·986	30·052	30·041	30·049	68·2	49·0
9	30·118	30·064	29·942	29·890	71·0	51·0	29·930	29·796	29·730	29·738	63·1	50·7
10	29·873	29·889	29·894	29·921	67·1	55·1	29·694	29·718	29·756	29·730	61·8	52·4
11	29·894	29·863	29·832	29·860	67·2	56·0	29·600	29·710	29·726	29·762	63·2	51·0
12	29·853	29·876	29·863	29·882	65·9	56·1	29·770	29·810	29·814	29·867	69·9	50·6
13	29·876	29·926	29·937	29·998	70·2	53·3	29·910	29·932	29·921	29·996	69·5	51·8
14	30·022	30·066	30·072	30·126	69·6	61·6	30·021	30·039	30·059	30·106	66·3	48·5
15	30·157	30·191	30·171	30·193	69·0	54·8	30·102	30·118	30·116	30·148	69·4	50·9
16	30·213	30·253	30·242	30·261	74·0	52·3	30·145	30·170	30·190	30·193	65·9	57·8
17	30·280	30·287	30·234	30·262	81·3	54·9	30·187	30·202	30·194	30·212	66·3	57·7
18	30·295	30·306	30·266	30·276	81·1	59·9	30·224	30·273	30·262	30·293	75·0	59·7
19	30·254	30·241	30·171	30·170	81·8	61·4	30·266	30·262	30·202	30·166	72·0	57·8
20	30·126	30·104	30·042	30·038	78·0	60·2	30·094	30·082	30·034	30·054	76·1	55·9
21	29·994	29·981	29·955	29·973	76·6	62·9	30·060	30·064	30·008	30·047	78·9	55·4
22	29·952	29·951	29·947	29·987	78·0	61·0	30·093	30·113	30·046	30·048	63·8	55·8
23	29·964	29·960	29·873	29·834	71·6	61·2	30·025	29·975	29·846	29·798	72·9	56·7
24	29·750	29·702	29·618	29·640	74·1	60·9	29·730	29·677	29·638	29·660	64·8	56·9
25	29·628	29·673	29·682	29·742	67·6	58·8	29·627	29·624	29·598	29·636	70·8	53·8
26	29·738	29·762	29·752	29·762	70·8	55·0	29·630	29·654	29·660	29·770	67·9	52·4
27	29·795	29·858	29·859	29·918	71·8	58·0	29·816	29·863	29·866	29·924	67·2	54·1
28	29·915	29·927	29·904	29·969	66·1	55·2	29·932	29·950	29·930	29·984	67·8	50·9
29	29·983	30·007	30·003	30·059	69·7	50·1	29·682	30·028	30·048	30·139	67·7	50·1
30	30·103	30·133	30·169	30·263	58·0	48·0	30·174	30·213	30·224	30·288	68·3	53·3
31	30·267	30·324	30·306	30·332	68·4	54·2	30·318	30·334	30·298	30·316	73·0	48·5

AUGUST, 1878.

1	30·311	30·279	30·135	30·105	70·1	54·9	30·314	30·304	30·202	30·224	75·2	50·7
2	30·039	29·964	29·873	29·789	69·3	55·0	30·202	30·166	30·122	30·123	65·9	53·5
3	29·667	29·660	29·664	29·719	64·8	54·0	30·080	30·018	29·944	29·962	69·0	53·8
4	29·699	29·713	29·714	29·808	70·2	56·0	29·918	29·898	29·854	29·868	72·3	59·5
5	29·822	29·845	29·802	29·792	77·1	57·5	29·844	29·846	29·836	29·858	70·9	57·1
6	29·706	29·688	29·646	29·712	75·0	59·9	29·818	29·747	29·646	29·637	67·7	55·4
7	29·724	29·792	29·818	29·913	73·1	59·1	29·586	29·579	29·585	29·646	67·9	59·4
8	29·962	30·031	30·058	30·124	74·5	58·0	29·680	29·783	29·894	30·000	65·9	52·8
9	30·111	30·102	29·994	29·926	75·3	54·0	30·013	29·992	29·908	29·840	67·7	48·4
10	29·752	29·669	29·619	29·673	71·8	61·5	29·702	29·616	29·540	29·592	64·0	51·3
11	.....	29·860	29·828	29·718	70·5	56·0	29·586	29·590	29·500	29·332	65·9	50·3
12	.....	29·525	29·552	29·649	68·8	55·0	29·186	29·286	29·314	29·228	65·8	53·8
13	29·657	29·664	29·631	29·521	66·3	55·0	29·200	29·292	29·326	29·294	64·9	52·8
14	29·229	29·339	29·460	29·590	72·1	58·6	29·214	29·274	29·336	29·422	69·1	50·0
15	29·600	29·599	29·540	29·500	69·3	57·4	29·432	29·428	29·388	29·370	57·9	47·6
16	29·409	29·380	29·381	29·510	67·5	56·0	29·306	29·308	29·362	29·471	63·9	48·3
17	29·675	29·868	29·919	29·996	66·1	52·0	29·546	29·596	29·553	29·680	58·9	43·9
18	30·013	30·043	29·971	29·929	71·6	53·0	29·792	29·868	29·902	29·956	66·8	54·8
19	29·849	29·810	29·806	29·873	70·1	57·0	29·918	29·918	29·885	29·902	64·9	50·2
20	29·890	29·913	29·918	29·968	65·3	53·9	29·898	29·922	29·910	29·948	62·3	52·7
21	29·996	30·012	29·973	29·988	68·0	53·1	29·954	29·967	29·948	29·966	60·9	53·7
22	29·940	29·908	29·825	29·735	67·9	56·2	29·958	29·982	29·906	29·910	66·1	51·3
23	29·543	29·485	29·449	29·444	70·1	57·0	29·824	29·776	29·724	29·703	60·4	49·2
24	29·407	29·412	29·409	29·447	67·1	57·2	29·642	29·590	29·506	29·500	60·8	52·9
25	29·456	29·491	29·484	29·499	66·8	54·0	29·429	29·422	29·407	29·435	64·2	56·9
26	29·465	29·465	29·486	29·579	69·1	51·9	29·422	29·424	29·413	29·455	68·0	51·6
27	29·629	29·642	29·640	29·665	69·4	59·0	29·470	29·482	29·463	29·481	66·9	53·3
28	29·684	29·740	29·736	29·790	67·9	59·0	29·484	29·556	29·600	29·678	69·5	54·5
29	29·711	29·587	29·512	29·462	70·1	56·9	29·674	29·662	29·562	29·474	61·0	54·0
30	29·244	29·372	29·467	29·522	67·5	58·4	29·346	29·364	29·384	29·456	61·0	55·9
31	29·543	29·609	29·682	29·814	66·0	58·0	29·460	29·594	29·669	29·766	64·1	55·2

BAROMETER READINGS, &c.

MAY, 1878.

	KEW.						GLASGOW.					
	Barometer.				Temperature.		Barometer.				Temperature.	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.
1	29·573	29·599	29·573	29·682	67·8	52·5	29·534	29·566	29·568	29·637	64·8	43·2
2	29·759	29·864	29·882	29·970	67·3	48·8	29·662	29·708	29·707	29·785	58·1	47·5
3	29·972	30·001	29·969	29·999	64·1	52·2	29·813	29·819	29·771	29·737	58·8	43·5
4	30·033	30·067	30·056	30·090	62·0	45·6	29·746	29·817	29·880	29·942	56·1	45·3
5	30·079	30·036	29·928	29·877	64·9	42·1	29·934	29·944	29·874	29·850	66·4	45·1
6	29·744	29·686	29·610	29·609	66·1	49·0	29·794	29·732	29·611	29·592	63·9	48·5
7	29·612	29·664	29·612	29·612	66·8	55·3	29·591	29·692	29·725	29·747	52·2	46·0
8	29·576	29·594	29·650	29·740	58·5	47·0	29·749	29·815	29·862	29·928	49·7	44·0
9	29·750	29·810	29·820	29·860	65·8	47·1	29·933	29·919	29·888	29·915	53·5	41·1
10	29·800	29·771	29·716	29·690	71·2	50·2	29·694	29·848	29·759	29·742	55·8	37·2
11	29·579	29·544	29·628	29·678	66·7	50·9	29·694	29·613	29·522	29·542	51·3	45·0
12	29·658	29·656	29·619	29·587	70·8	49·5	29·528	29·534	29·501	29·500	65·4	45·8
13	29·491	29·552	29·536	29·553	62·3	51·8	29·445	29·367	29·318	29·315	59·4	51·5
14	29·483	29·455	29·463	29·559	62·3	51·0	29·253	29·214	29·163	29·175	61·2	50·2
15	29·514	29·448	29·481	29·560	61·0	52·6	29·193	29·149	29·071	29·211	56·4	50·1
16	29·684	29·807	29·817	29·772	61·9	50·0	29·329	29·502	29·459	29·279	60·4	48·0
17	29·775	29·881	29·996	30·042	66·8	57·0	29·271	29·366	29·645	29·787	59·8	50·7
18	29·884	29·804	29·837	29·903	69·1	52·0	29·731	29·539	29·488	29·506	63·2	48·7
19	29·833	29·848	29·805	29·852	61·0	51·8	29·450	29·363	29·362	29·530	56·9	47·7
20	29·866	29·834	29·752	29·795	56·9	43·8	29·612	29·705	29·749	29·731	50·1	40·5
21	29·881	29·887	29·858	29·905	55·2	39·1	29·641	29·647	29·666	29·701	50·0	36·5
22	29·908	29·937	29·905	29·830	58·0	41·9	29·751	29·755	29·717	29·655	54·9	42·5
23	29·639	29·428	29·322	29·340	61·0	46·9	29·511	29·390	29·331	29·327	53·3	44·9
24	29·312	29·278	29·255	29·356	59·6	49·0	29·327	29·367	29·391	29·440	53·2	45·3
25	29·512	29·634	29·671	29·747	59·0	45·0	29·445	29·496	29·508	29·557	57·9	39·5
26	29·737	29·771	29·765	29·796	60·4	45·0	29·562	29·364	29·554	29·585	57·4	40·5
27	29·776	29·774	29·748	29·791	62·1	47·0	29·580	29·526	29·649	29·727	57·4	44·3
28	29·770	29·773	29·725	29·796	62·7	45·0	29·765	29·839	29·886	29·974	59·3	44·7
29	29·772	29·914	30·010	30·113	56·7	49·2	30·025	30·093	30·091	30·116	61·9	46·7
30	30·113	30·128	30·084	30·063	55·0	42·0	30·096	30·062	30·026	30·028	63·0	42·7
31	30·028	29·998	29·928	29·922	63·1	39·7	30·013	29·986	29·934	29·965	64·1	46·1

JUNE, 1878.

1	29·933	29·992	30·010	30·031	56·4	45·1	29·992	29·998	29·958	29·948	60·4	42·8
2	30·021	30·015	29·961	29·934	63·1	44·0	29·954	29·941	29·900	29·903	58·3	45·3
3	29·884	29·915	29·894	29·877	67·2	51·0	29·876	29·909	29·896	29·878	54·4	45·2
4	29·794	29·750	29·737	29·795	64·3	52·1	29·820	29·792	29·806	29·886	52·9	42·4
5	29·880	30·033	30·094	30·136	57·8	47·5	29·946	29·994	30·005	30·043	60·1	40·8
6	.....	30·200	30·179	30·191	67·4	46·1	30·075	30·127	30·088	30·078	59·2	42·0
7	.....	30·152	30·047	29·981	68·0	50·5	30·002	29·914	29·832	29·814	59·4	46·0
8	.....	29·749	29·627	29·605	70·2	53·7	29·665	29·614	29·473	29·331	61·3	53·1
9	29·618	29·595	29·516	29·543	65·1	54·6	29·305	29·352	29·313	29·327	64·3	50·1
10	29·644	29·726	29·756	29·800	64·7	52·3	29·327	29·372	29·453	29·533	63·0	50·4
11	29·701	29·575	29·445	29·523	63·0	51·4	29·517	29·407	29·468	29·222	57·0	47·9
12	29·559	29·555	29·566	29·706	64·0	50·0	29·248	29·374	29·522	29·664	57·0	50·0
13	29·767	29·820	29·796	29·832	66·6	51·7	29·746	29·814	29·831	29·920	60·2	47·3
14	29·832	29·864	29·856	29·871	56·7	49·0	29·923	29·933	29·868	29·862	57·0	47·7
15	29·856	29·857	29·831	29·828	59·8	44·9	29·820	29·802	29·753	29·791	60·8	48·2
16	29·793	29·795	29·753	29·780	62·1	50·0	29·809	29·799	29·769	29·786	66·0	44·7
17	29·774	29·825	29·820	29·859	64·8	49·0	29·737	29·740	29·751	29·779	62·9	47·8
18	29·856	29·877	29·865	29·893	65·0	51·0	29·765	29·974	29·772	29·818	63·6	48·7
19	29·893	29·933	29·944	30·002	66·2	49·4	29·848	29·902	29·912	29·972	64·9	47·4
20	30·017	30·033	30·015	30·062	71·2	47·5	29·962	29·940	29·877	29·890	69·0	47·9
21	30·083	30·097	30·090	30·130	73·7	46·4	29·827	29·915	29·975	30·055	64·8	52·7
22	30·157	30·164	30·111	30·109	76·6	50·0	30·083	30·095	30·040	30·033	69·6	49·0
23	30·082	30·062	30·026	30·029	78·5	56·8	30·008	29·996	29·982	29·952	66·2	48·3
24	30·033	30·061	30·046	30·096	80·5	57·9	29·916	29·946	29·967	29·992	64·0	56·9
25	30·106	30·156	30·134	30·160	82·1	61·4	30·000	30·045	30·048	30·062	72·0	58·1
26	30·150	30·154	30·108	30·134	85·1	57·5	30·062	30·070	30·055	30·078	77·7	54·6
27	30·090	30·068	29·986	29·962	83·9	63·6	30·041	29·986	29·928	29·940	85·0	68·4
28	29·900	29·896	29·871	29·872	79·9	63·4	29·952	29·966	29·963	30·023	81·1	56·2
29	29·835	29·814	29·758	29·755	77·7	58·2	30·035	29·993	29·911	29·915	73·0	54·5
30	29·722	29·756	29·710	29·864	70·3	55·0	29·909	29·915	29·897	29·963	71·2	54·5

BAROMETER READINGS, &c.

JULY, 1878.

KEW.							GLASGOW.						
	BAROMETER.				TEMPERATURE.			BAROMETER.				TEMPERATURE.	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.
1	29·883	29·897	29·866	29·845	67·0	54·3	1	29·946	29·940	29·915	29·943	64·6	52·8
2	29·828	29·837	29·812	29·862	62·0	53·0	2	29·916	29·901	29·857	29·855	63·5	51·0
3	29·865	29·903	29·938	30·067	61·3	52·4	3	29·848	29·906	29·926	29·990	67·9	50·3
4	30·101	30·126	30·089	30·110	69·9	47·1	4	29·988	29·974	29·928	29·842	59·3	48·9
5	30·098	30·090	30·064	30·046	70·1	54·6	5	29·804	29·814	29·762	29·730	63·3	58·2
6	29·987	29·976	29·948	29·981	74·8	58·1	6	29·724	29·767	29·798	29·835	65·3	55·8
7	29·969	29·973	29·950	29·960	72·1	55·4	7	29·820	29·842	29·867	29·928	66·8	53·9
8	29·984	30·051	30·089	30·126	68·8	56·2	8	29·986	30·052	30·041	30·049	68·2	49·0
9	30·118	30·064	29·942	29·890	71·0	51·0	9	29·930	29·796	29·730	29·738	63·1	50·7
10	29·873	29·889	29·894	29·921	67·1	55·1	10	29·694	29·718	29·756	29·730	61·8	52·4
11	29·894	29·863	29·832	29·860	67·2	56·0	11	29·690	29·710	29·726	29·762	63·2	51·0
12	29·853	29·876	29·863	29·882	65·9	56·1	12	29·770	29·810	29·814	29·867	69·9	50·6
13	29·876	29·926	29·937	29·998	70·2	53·3	13	29·910	29·932	29·921	29·996	69·5	51·8
14	30·022	30·066	30·072	30·126	69·6	61·6	14	30·021	30·039	30·059	30·106	66·3	48·5
15	30·157	30·191	30·171	30·193	69·0	54·8	15	30·102	30·118	30·116	30·148	69·4	50·9
16	30·213	30·253	30·242	30·261	74·0	52·3	16	30·145	30·170	30·190	30·193	65·9	57·8
17	30·280	30·287	30·234	30·262	81·3	54·9	17	30·187	30·202	30·194	30·212	66·3	57·7
18	30·295	30·306	30·266	30·276	81·1	59·9	18	30·224	30·273	30·262	30·293	75·0	59·7
19	30·254	30·241	30·171	30·170	81·8	61·4	19	30·266	30·262	30·202	30·166	72·0	57·8
20	30·126	30·104	30·042	30·038	78·0	60·2	20	30·094	30·082	30·034	30·054	76·1	55·9
21	29·994	29·981	29·955	29·973	76·6	62·9	21	30·060	30·064	30·008	30·047	78·9	55·4
22	29·952	29·951	29·947	29·987	78·0	61·0	22	30·093	30·113	30·046	30·048	63·8	55·8
23	29·964	29·960	29·873	29·834	71·6	61·2	23	30·025	29·975	29·846	29·798	72·9	56·7
24	29·750	29·702	29·618	29·640	74·1	60·9	24	29·730	29·677	29·638	29·660	64·8	56·9
25	29·628	29·673	29·682	29·742	67·6	58·8	25	29·627	29·624	29·598	29·636	70·8	53·8
26	29·738	29·762	29·752	29·762	70·8	55·0	26	29·630	29·654	29·660	29·770	67·9	52·4
27	29·795	29·858	29·859	29·918	71·8	58·0	27	29·816	29·863	29·866	29·924	67·2	54·1
28	29·915	29·927	29·904	29·969	66·1	55·2	28	29·932	29·950	29·930	29·984	67·8	50·9
29	29·983	30·007	30·003	30·059	69·7	50·1	29	29·682	30·028	30·048	30·139	67·7	50·1
30	30·103	30·133	30·169	30·263	58·0	48·0	30	30·174	30·213	30·224	30·288	68·3	53·3
31	30·267	30·324	30·306	30·332	68·4	54·2	31	30·318	30·334	30·298	30·316	73·0	48·5

AUGUST, 1878.

1	30·311	30·279	30·135	30·105	70·1	54·9	1	30·314	30·304	30·202	30·224	75·2	50·7
2	30·039	29·964	29·873	29·789	69·3	55·0	2	30·202	30·166	30·122	30·123	65·9	53·5
3	29·667	29·660	29·664	29·719	64·8	54·0	3	30·080	30·018	29·944	29·962	69·0	53·8
4	29·699	29·713	29·714	29·808	70·2	56·0	4	29·918	29·898	29·854	29·868	72·3	59·5
5	29·822	29·845	29·802	29·792	77·1	57·5	5	29·844	29·846	29·836	29·858	70·9	57·1
6	29·706	29·688	29·646	29·712	75·0	59·9	6	29·818	29·747	29·646	29·637	67·7	55·4
7	29·724	29·792	29·818	29·913	73·1	59·1	7	29·586	29·579	29·585	29·646	67·9	59·4
8	29·962	30·031	30·058	30·124	74·5	58·0	8	29·680	29·783	29·894	30·000	65·9	52·8
9	30·111	30·102	29·994	29·926	75·3	54·0	9	30·013	29·992	29·908	29·840	67·7	48·4
10	29·752	29·669	29·619	29·673	71·8	61·5	10	29·702	29·616	29·540	29·592	64·0	51·3
11	.....	29·860	29·828	29·718	70·5	56·0	11	29·586	29·590	29·500	29·332	65·9	50·3
12	.....	29·525	29·552	29·649	68·8	55·0	12	29·186	29·286	29·314	29·228	65·8	53·8
13	29·657	29·664	29·631	29·521	66·3	55·0	13	29·200	29·292	29·326	29·294	64·9	52·8
14	29·229	29·339	29·460	29·590	72·1	58·6	14	29·214	29·274	29·336	29·422	69·1	50·0
15	29·600	29·599	29·540	29·500	69·3	57·4	15	29·432	29·428	29·388	29·370	57·9	47·6
16	29·409	29·380	29·381	29·510	67·5	56·0	16	29·306	29·308	29·362	29·471	63·9	48·3
17	29·675	29·868	29·919	29·996	66·1	52·0	17	29·546	29·596	29·553	29·680	58·9	43·9
18	30·013	30·043	29·971	29·929	71·6	53·0	18	29·792	29·868	29·902	29·956	66·8	54·8
19	29·849	29·810	29·806	29·873	70·1	57·0	19	29·918	29·918	29·885	29·902	64·9	50·2
20	29·890	29·913	29·918	29·968	65·3	53·9	20	29·898	29·922	29·910	29·948	62·3	52·7
21	29·996	30·012	29·973	29·988	68·0	53·1	21	29·954	29·967	29·948	29·996	60·9	53·7
22	29·940	29·908	29·825	29·735	67·9	56·2	22	29·958	29·982	29·906	29·910	66·1	51·3
23	29·543	29·485	29·449	29·444	70·1	57·0	23	29·824	29·776	29·724	29·703	60·4	49·2
24	29·407	29·412	29·409	29·447	67·1	57·2	24	29·642	29·590	29·506	29·500	60·8	52·9
25	29·456	29·491	29·484	29·499	66·8	54·0	25	29·429	29·432	29·407	29·435	64·2	56·9
26	29·465	29·465	29·486	29·570	69·1	51·9	26	29·422	29·424	29·413	29·455	68·0	51·6
27	29·629	29·642	29·640	29·665	69·4	59·0	27	29·470	29·482	29·463	29·481	66·9	53·3
28	29·684	29·740	29·736	29·790	67·9	59·0	28	29·484	29·556	29·600	29·678	69·5	54·5
29	29·711	29·587	29·512	29·462	70·1	56·9	29	29·674	29·662	29·562	29·474	61·0	54·0
30	29·244	29·372	29·467	29·522	67·5	58·4	30	29·346	29·364	29·384	29·456	61·0	55·9
31	29·543	29·609	29·682	29·814	66·0	58·0	31	29·460	29·594	29·669	29·766	64·1	55·2

BAROMETER READINGS, &c.

SEPTEMBER, 1878.

	KEW.						GLASGOW.					
	Barometer.				Temperature.		Barometer.				Temperature.	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.
1	29·875	30·001	30·080	30·162	62·5	57·3	29·850	29·942	29·994	30·077	65·0	50·4
2	30·209	30·263	30·247	30·262	65·6	53·0	30·096	30·105	30·004	29·956	66·8	51·4
3	30·244	30·257	30·180	30·171	69·2	49·9	29·915	29·937	29·975	30·020	65·0	58·7
4	30·150	30·139	30·053	30·030	71·3	50·0	30·036	30·068	30·056	30·041	64·3	58·5
5	29·957	29·962	29·954	29·993	71·7	58·9	29·980	29·978	29·902	29·908	66·9	55·0
6	30·001	30·095	30·076	30·110	71·6	55·0	29·890	29·930	29·940	29·956	65·0	51·7
7	30·112	30·118	30·058	30·053	71·7	50·0	30·006	30·056	30·040	30·057	66·5	57·0
8	29·999	30·001	29·952	29·989	62·7	55·0	30·028	29·988	29·894	29·770	68·6	54·2
9	29·989	30·021	30·022	30·086	68·1	53·6	29·792	29·934	30·050	30·090	63·0	48·2
10	30·132	30·196	30·189	30·245	67·0	51·3	30·122	30·122	30·108	30·102	62·8	49·8
11	30·237	30·255	30·180	30·185	69·8	47·0	30·046	30·060	30·027	29·972	65·8	58·1
12	30·119	30·051	30·036	30·124	66·6	48·7	29·812	30·022	30·049	30·078	60·2	51·7
13	30·103	30·108	30·035	30·021	64·8	45·6	29·996	29·962	29·886	29·736	64·0	51·2
14	29·973	30·009	29·962	29·965	67·5	44·3	29·772	29·780	29·790	29·676	63·2	54·9
15	29·900	29·810	29·623	29·492	65·0	54·5	29·416	29·079	28·995	28·927	61·0	47·6
16	29·619	29·773	29·921	30·033	61·3	50·6	29·051	29·307	29·556	29·632	54·2	46·5
17	30·008	29·981	29·921	29·865	65·5	50·7	29·488	29·524	29·480	29·343	62·5	52·9
18	29·652	29·610	29·678	29·800	62·0	48·9	29·330	29·376	29·368	29·368	54·9	43·4
19	29·848	29·912	29·856	29·770	59·6	46·0	29·423	29·473	29·504	29·574	52·0	43·1
20	29·742	29·858	29·944	30·092	58·0	44·0	29·746	29·928	29·976	30·028	51·8	42·6
21	30·135	30·174	30·142	30·118	58·1	40·0	30·004	30·022	29·980	29·867	55·9	43·9
22	30·020	29·906	29·726	29·543	57·4	46·2	29·668	29·582	29·422	29·439	55·0	45·4
23	29·452	29·458	29·430	29·481	58·0	45·8	29·372	29·304	29·338	29·473	50·7	43·7
24	29·516	29·622	29·663	29·740	58·5	37·0	29·538	29·632	29·614	29·536	57·5	50·1
25	29·724	29·705	29·604	29·707	58·1	41·3	29·327	29·333	29·470	29·606	55·2	42·8
26	29·824	29·956	29·990	30·053	59·0	42·1	29·653	29·704	29·746	29·790	53·5	41·5
27	30·051	30·068	30·043	30·083	59·1	42·8	29·810	29·880	29·904	29·955	55·2	44·2
28	30·080	30·088	30·043	30·047	66·0	53·1	29·936	29·944	29·910	29·950	60·2	43·8
29	30·017	30·027	29·942	29·873	64·2	49·9	29·949	29·952	29·884	29·786	51·9	48·8
30	29·690	29·675	29·744	29·855	62·1	48·5	29·619	29·636	29·754	29·888	50·9	45·9

OCTOBER, 1878.

1	29·924	30·019	30·025	30·137	62·4	48·7	1	29·956	30·031	30·074	30·166	52·8	29·3
2	30·229	30·202	30·251	30·236	61·5	40·9	2	30·192	30·182	30·086	30·016	53·3	34·3
3	30·191	30·201	30·139	30·174	65·0	45·1	3	29·918	29·966	29·970	29·992	59·9	52·2
4	30·133	30·155	30·090	30·114	64·0	44·1	4	29·976	29·995	29·948	29·949	55·2	50·5
5	30·104	30·102	30·018	29·966	70·8	46·9	5	29·940	29·936	29·854	29·793	63·1	52·4
6	29·838	29·793	29·723	29·637	69·0	54·1	6	29·665	29·576	29·477	29·460	61·2	57·0
7	29·543	29·546	29·496	29·382	64·7	58·2	7	.....	29·292	29·268	29·180	62·1	55·8
8	29·320	29·380	29·435	29·536	65·0	55·9	8	28·964	28·945	28·968	29·050	60·2	54·9
9	29·610	29·594	29·443	29·388	61·7	53·6	9	29·184	29·136	28·992	28·952	57·9	52·0
10	29·249	29·225	29·350	29·564	61·0	53·2	10	28·799	28·724	28·772	29·088	58·7	52·1
11	29·705	29·871	29·987	30·110	57·3	44·9	11	29·286	29·520	29·730	29·874	52·3	47·8
12	30·173	30·242	30·252	30·294	58·9	39·2	12	29·994	30·070	30·066	30·022	55·7	46·5
13	30·303	30·314	30·249	30·221	60·0	34·1	13	29·966	29·968	29·930	29·918	57·0	52·4
14	30·163	30·139	30·033	29·995	60·2	38·0	14	29·912	29·942	29·914	29·915	56·9	50·1
15	29·925	29·950	29·950	30·000	56·3	45·0	15	29·946	30·015	30·008	30·030	55·9	44·2
16	30·000	30·050	30·020	30·030	56·2	52·0	16	30·002	29·976	29·904	29·880	54·3	48·4
17	29·990	29·980	29·921	29·930	54·5	44·2	17	29·808	29·829	29·808	29·862	57·5	49·5
18	29·865	29·832	29·733	29·718	54·7	48·9	18	29·840	29·862	29·812	29·832	56·6	47·8
19	29·665	29·723	29·750	29·790	56·1	51·9	19	29·762	29·748	29·721	29·748	58·5	50·8
20	29·780	29·800	29·750	29·690	58·6	48·0	20	29·705	29·659	29·514	29·336	55·4	49·9
21	29·570	29·486	29·300	29·200	62·4	51·0	21	29·168	29·011	29·782	29·782	54·3	40·0
22	29·150	29·230	29·251	29·303	57·0	43·5	22	28·798	28·829	28·940	28·798	50·0	39·9
23	29·443	29·514	29·583	29·600	53·2	41·8	23	28·973	29·044	29·054	29·086	46·4	42·2
24	29·530	29·146	29·267	29·336	58·1	45·1	24	29·106	29·040	28·974	29·003	46·3	41·8
25	29·248	29·199	29·215	29·217	54·0	44·8	25	28·970	28·944	28·850	28·906	46·7	40·0
26	29·080	28·988	29·132	29·283	53·8	40·1	26	28·946	29·079	29·156	29·275	48·7	40·1
27	29·339	29·462	29·554	29·676	50·1	34·7	27	29·370	29·516	29·562	29·552	51·0	38·0
28	29·700	29·704	29·661	29·653	50·8	37·7	28	29·444	29·378	29·402	29·683	46·6	38·8
29	29·702	29·789	29·732	29·744	45·1	35·1	29	29·728	29·731	29·716	29·638	42·4	33·8
30	29·741	29·674	29·650	29·609	45·1	33·8	30	29·539	29·639	29·759	29·846	45·6	38·2
31	29·775	29·865	29·862	29·898	44·3	31·3	31	29·920	29·940	29·980	29·972	43·9	32·2

BAROMETER READINGS, &c.

NOVEMBER, 1878.

KEW.							GLASGOW.						
	BAROMETER.				TEMPERATURE.			BAROMETER.				TEMPERATURE.	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.
1	29·882	29·923	29·944	30·028	48·2	39·2	1	30·006	30·090	30·102	30·142	46·1	32·8
2	30·051	30·113	30·152	30·220	47·7	33·5	2	30·177	30·268	30·261	30·256	46·3	34·7
3	30·217	30 178	30·100	30·040	45·5	32·0	3	30·224	30·204	30·118	30 028	44·8	35·8
4	29·905	29·764	29·662	29·655	43·3	32·2	4	29·866	29·835	29·864	29·938	46·0	36·0
5	29·696	29·795	29·772	29·707	45·0	37·8	5	29·966	29·947	29·826	29·976	46 2	31·0
6	29·607	29·538	29·496	29·578	44·3	36·2	6	29·674	29·628	29·678	29·746	46·3	36·0
7	29·628	29·714	29·753	29·771	46·2	32·8	7	29·756	29·748	29·625	29·478	43·9	34·3
8	29·639	29·383	29·394	29·682	45·0	33·2	8	29·364	29·531	29·729	29·850	39·0	33·2
9	29 958	30·152	30·180	30·060	44·1	34·0	9	30·004	30·022	29·814	29·314	46·3	30·4
10	29·698	29·441	29·218	29·274	51·1	41·0	10	29·129	29·032	28·975	29·127	47·0	39·7
11	29·323	29·509	29·516	29·379	45·0	34·7	11	29·268	29·340	29·263	29·266	40·2	30·3
12	29·381	29·421	29·403	29·380	38·3	32·1	12	29·242	29·304	29·340	29·440	44·0	32·0
13	29·363	29·411	29·433	29·465	41·0	35·0	13	29·428	29·558	29·616	29·708	45·7	33·3
14	29·445	29·463	29·450	29·397	43·6	38·0	14	29·710	29·748	29·733	29·718	44·0	30·8
15	29·301	29·235	29·171	29·178	42·6	38·0	15	29·668	29·648	29·533	29·452	44·9	37·6
16	29·182	29·256	29·303	29·361	45·0	40·3	16	29·340	29·396	29·264	29·542	45·9	39·7
17	29·413	29·521	29·561	29·600	45·5	40·6	17	29·599	29·738	29·834	29·966	46·9	36·9
18	29·715	29·947	30·062	30·210	47·3	38·7	18	30·060	30·175	30·226	30·278	37·6	29·9
19	30·296	30·309	30·410	30·446	46·1	34·3	19	30·298	30·320	30·304	30 308	44·6	30·0
20	30·397	30·380	30·310	30·257	43·7	35·5	20	30·288	30·289	30·262	30·236	46·2	40·1
21	30·159	30·119	30·066	30·052	41·9	38·9	21	30·158	30·118	3 ·032	29 986	46·8	41·1
22	30·023	30·042	30 018	30·028	40·1	36·8	22	29·908	29·886	29·841	29·876	43·8	37·3
23	30·006	30·004	29·915	29·872	42·3	30·1	23	29·904	29·931	29·882	29·846	37·9	34·1
24	29·693	29·528	29·419	29·352	51·3	36 1	24	29·722	29·570	29·432	29·356	39·9	35·8
25	29·282	29·314	29·376	29·396	52·4	40·0	25	29·386	29·294	29·294	29·366	40·5	34·9
26	29·392	29·477	29·440	29·434	41·0	38·7	26	29·412	29·482	29·489	29·542	39·0	33·0
27	29·402	29·401	29·317	29·296	42·1	36·6	27	29·525	29·563	29·556	29·682	37·1	29·0
28	29·350	29·522	29·632	29·763	42·0	38·9	28	29·790	29·934	29·953	29·989	38·9	28·2
29	29 828	29·912	29·913	29·929	39·3	29·3	29	29·896	29·795	29·978	29·889	36·1	26·8
30	29·930	29·979	29·952	29·934	38·0	29·6	30	29·896	29·894	29·796	29·724	40·5	33·7

DECEMBER, 1878.

1	29·860	29·742	29·586	29·714	40·1	33·8	1	29·672	29·674	29·786	29·928	42·8	35·3
2	29·860	29·990	30·000	30·005	40·3	34·6	2	30·018	30·089	30·108	30·160	40·0	33·5
3	30·017	30·110	30·162	30·202	39·5	34·9	3	30·160	30·242	30·269	30·308	39·3	31·1
4	30·222	30·226	30·191	30·169	41·4	34·9	4	30·294	30·270	30·199	30·138	39·9	27·7
5	30·115	30·066	29·988	30·028	44·4	33·8	5	30·099	30·092	30·178	30·214	41·3	31·5
6	30·053	30·060	29·957	29·805	37·1	29·8	6	30 118	29·998	29·781	29·764	38·8	30·3
7	29·649	29·641	29·599	29·557	36·8	34·1	7	29·750	29·768	29·740	29·674	37·9	31·0
8	29·494	29·467	29·465	29·538	34·4	31·9	8	29·564	29·572	29·616	29·614	36·5	28·2
9	29·582	29·622	29·623	29·706	34·2	25·5	9	29·594	29·641	29·673	29·730	36·0	27·9
10	29·760	29·820	29·829	29·854	28·7	25 5	10	29·764	29·874	29·910	29 950	34·5	28·1
11	29·844	29 858	29·868	29·826	33·7	29·0	11	29·960	29·980	29·886	29·750	32·0	24·9
12	29·812	29·804	29·710	29·654	30 0	27·1	12	29·623	29·580	29·500	29·516	32·4	21·8
13	29·598	29·646	29·663	29·672	30·0	22·0	13	29·522	29 578	29 592	29·638	30·2	21·2
14	29·613	29·587	29·568	29·641	30·9	22·0	14	29·636	29·630	29·600	29·590	26·1	20·0
15	29·664	29·685	29·639	29·691	35·0	23·2	15	29·537	29·488	29·455	29·399	31·0	20·2
16	29·503	29·477	29·418	29·432	33·4	29·0	16	29·390	29·430	29·420	29·484	28·2	16·7
17	29·420	29·446	29·459	29·505	32·1	24·4	17	29·449	29·422	29·324	29·112	34·5	14·7
18	29·437	29·326	29·242	29·189	39·8	31·1	18	28·984	28·822	28 932	28·988	35·8	28·3
19	29 133	29·182	29·269	29·399	38·5	31·1	19	29·029	29·126	29·256	29 385	37·8	24·3
20	29·439	29·485	29·511	29·629	32·8	27·5	20	29·410	29·462	29·520	29·639	32·1	11·9
21	29·693	29·785	29·807	29·828	32·9	27·5	21	29·711	29·707	29·608	29·582	34·6	24·0
22	29·758	29·764	29·735	29·789	32·6	23·1	22	29·590	29·589	29·632	29·672	34·1	24·6
23	29·810	29·853	29·900	29 999	30·7	16·9	23	29·674	29·773	29·944	30·089	35·0	20·8
24	30·181	30·322	30·338	30·342	30·0	14·7	24	30·182	30·248	30·211	30·140	29·0	14·0
25	30 212	30·068	29·784	29·655	32·9	16·0	25	30·047	29·970	29·819	29·725	28·9	22 0
26	29·478	29·409	29·398	29·421	46·0	32·2	26	29·578	29·488	29·446	29·450	34·9	25·9
27	29·378	29·382	29·452	29·366	45·0	35·1	27	29·433	29·444	29·396	29 356	34·9	30·0
28	29·512	29·620	29·557	29·418	46·8	37·9	28	29·354	29·402	29·342	29·263	37·0	27·9
29	29·279	29·469	29·496	29·476	46·9	38·2	29	29·120	29·172	29·264	29·208	39·2	32·2
30	29·370	29·469	29·474	29·500	53·6	46·2	30	28·928	28·986	28·968	29·002	45·7	35·7
31	29·473	29 529	29·479	29·561	53·2	49·0	31	28·858	28·888	28·756	29·014	47·9	40·0

WIND AT THE OBSERVATORIES of KEW & GLASGOW TOGETHER WITH THE EXPLOSIONS OF FIREDAMP IN ENGLAND & SCOTLAND

1878.

ANUARY.

:BRUARY.

are firm
- dotted
s attached to the
shew the N°s of deaths
; the explosions

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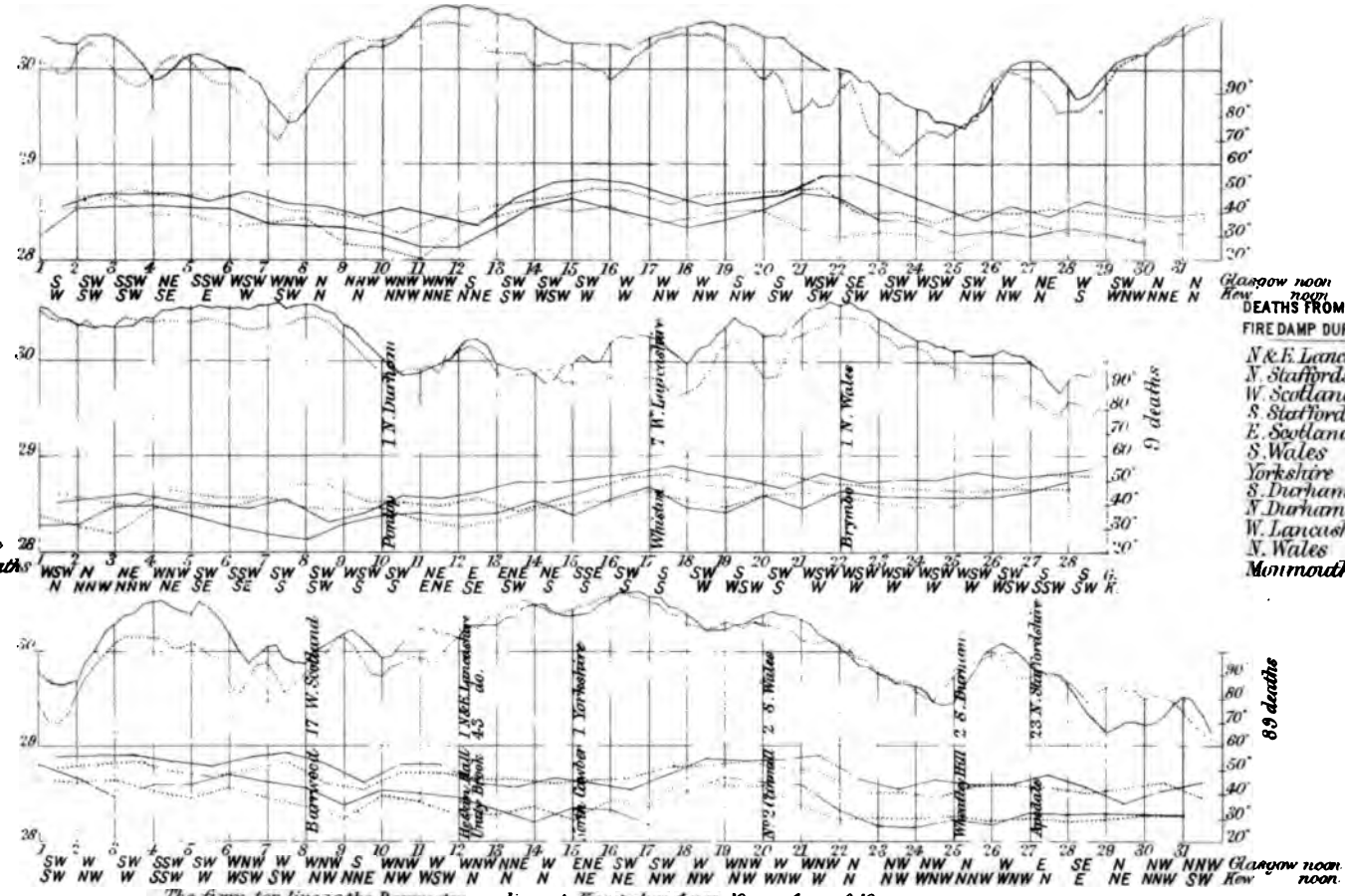


DEATHS FROM EXPLOSIONS OF FIREDAMP DURING THE YEAR 1878.

N. & E. Lancashire	45	deaths.
N. Staffordshire	28	"
W. Scotland	22	"
S. Staffordshire	1	"
E. Scotland	2	"
S. Wales	7	"
Yorkshire	4	"
S. Durham	4	"
N. Durham	1	"
W. Lancashire	196	"
N. Wales	8	"
Monmouth	268	"
	586	

The firm top line is the Barometer reading at Kew taken 4 a.m. 10 a.m. 4 p.m. & 10 p.m.
The dotted top line is the Barometer reading at Glasgow taken do. do. do. do.
The lower lines are the Maxima and Minima temperatures at Kew & Glasgow observed respectively at 10 a.m. & 10 p.m.

...s N°E.I. of M&ME. 1878-79

And^r Reid, Newcastle.

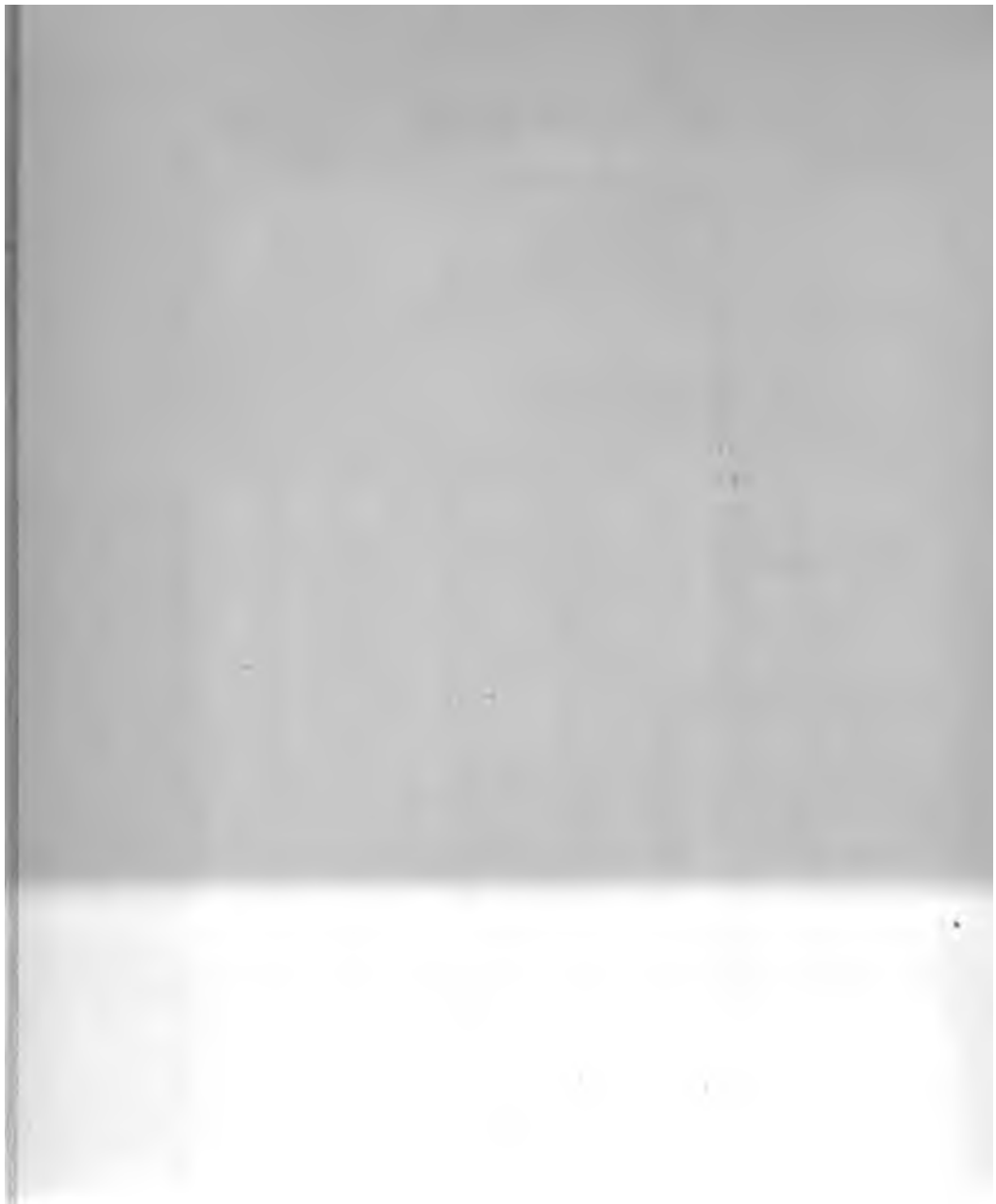
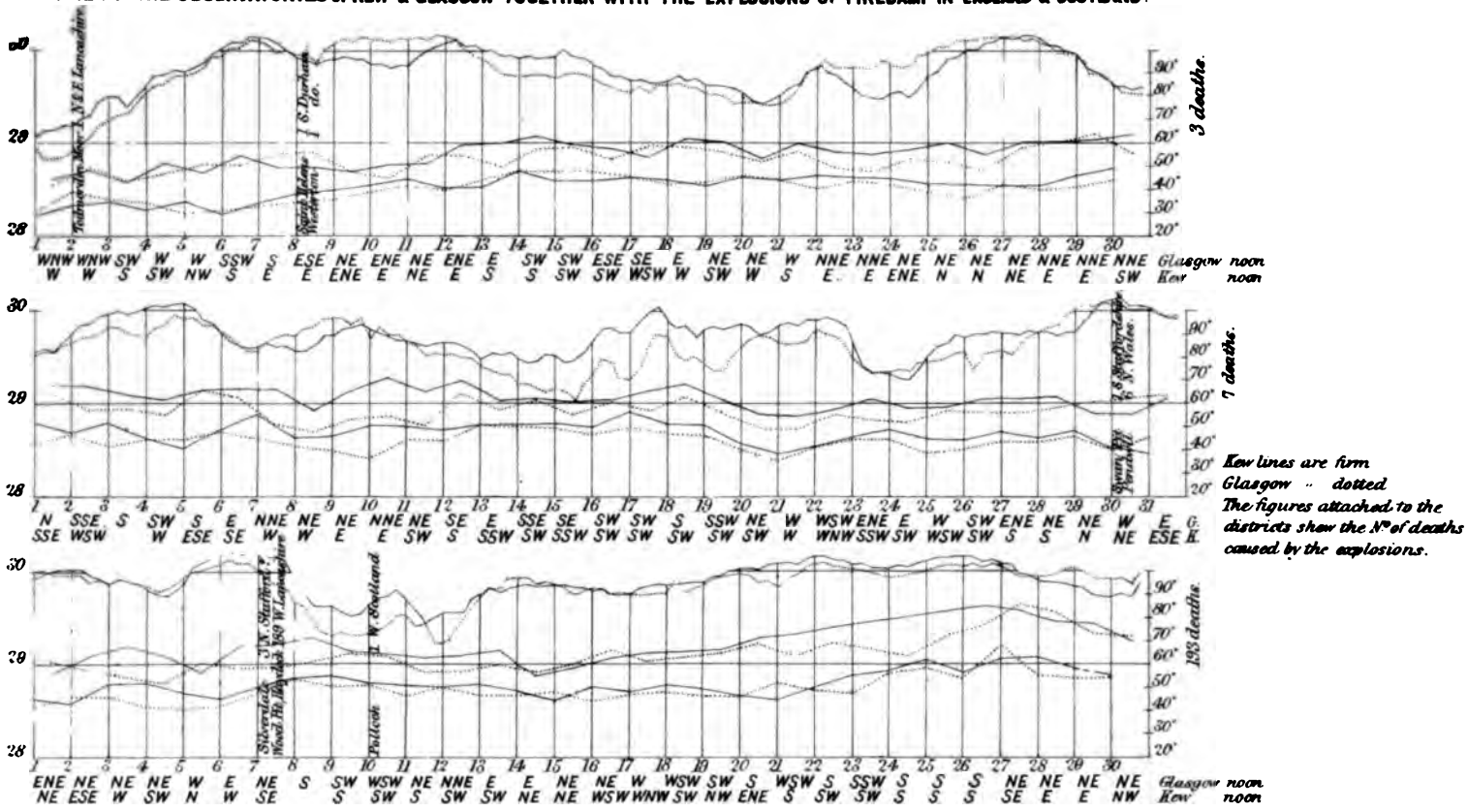


DIAGRAM SHEWING THE HEIGHT OF THE BAROMETER, THE MAXIMA & MINIMA TEMPERATURES & THE DIRECTION OF THE WIND AT THE OBSERVATORIES of KEW & GLASGOW TOGETHER WITH THE EXPLOSIONS OF FIREDAMP IN ENGLAND & SCOTLAND.



AY

JNE

Kew lines are firm
Glasgow .. dotted
The figures attached to the districts shew the N° of deaths caused by the explosions.

The firm top line is the Barometer reading at Kew taken 4 a.m. 10 a.m. 4 p.m & 10 p.m.
The dotted top line is the Barometer reading at Glasgow taken do. do. do. do.
The lower lines are the Maxima and Minima temperatures at Kew & Glasgow observed respectively at 10 a.m. & 10 p.m.

N° E. I of M & M.E. 1878-79.

Andᵂ Reid, Newcastle

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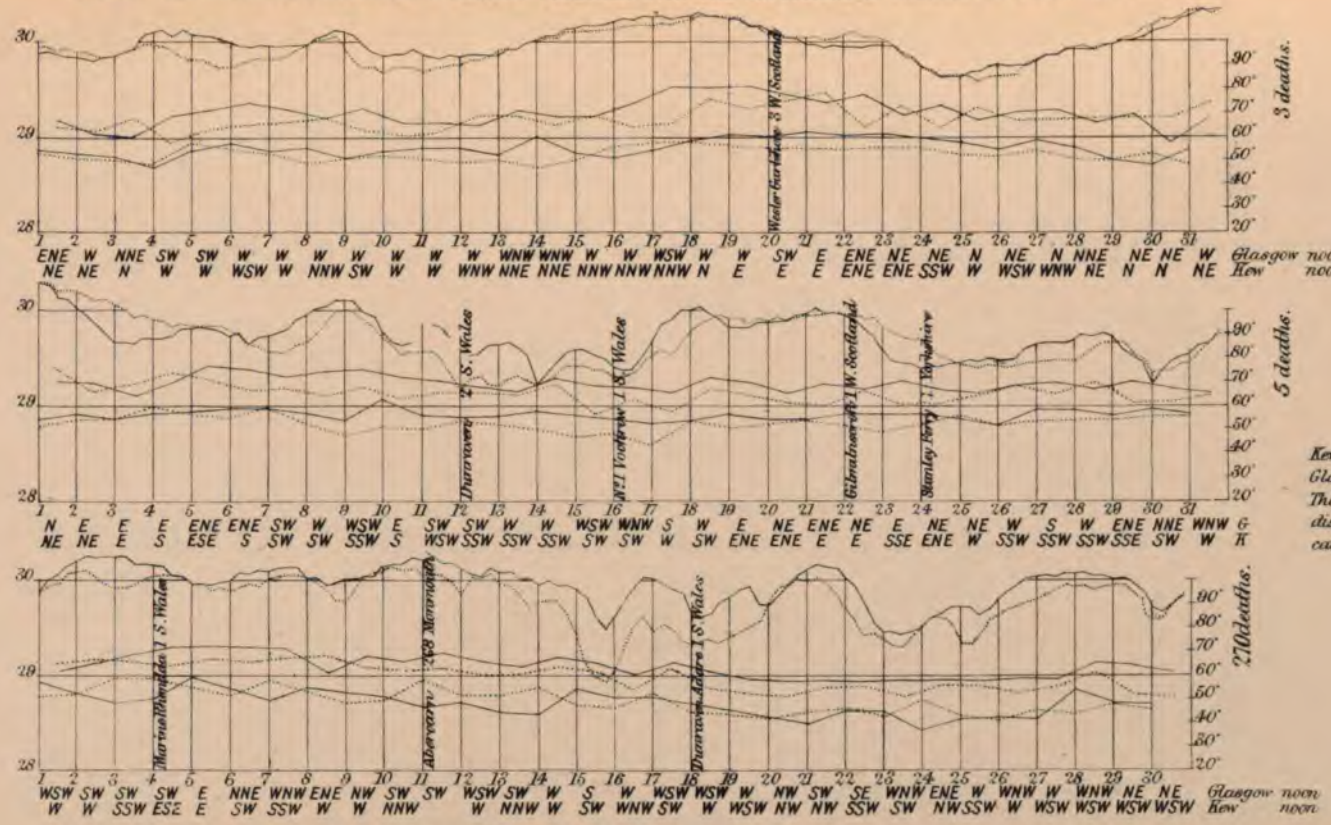
WIND AT THE OBSERVATORIES of KEW & GLASGOW TOGETHER WITH THE EXPLOSIONS OF FIREDAMP IN ENGLAND & SCOTLAND.


30
29
28
Wealer Garforth & W. Scotland
3 deaths.
90°
80°
70°
60°
50°
40°
30°
20°
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
ENE W NNE SW SW W W W W W W W WNW WNW W W WSW W W SW E ENE NE NE N NE N NNE NE NE W Glasgow noon
NE NE N W W WSW W NNW SW W W WNW NNE NNE NNW NNW NNW N E E E ENE ENE SSW W WSW WNW NE N N NE Kew noon
Pumpherston & S. Wales
Tredegar & S. Wales
Gibraltar & W. Scotland
Stanley Pit, Lancashire
5 deaths.
N E E E ENE ENE SW W WSW E SW SW W W WSW WNW S W E NE ENE NE E NE NE W S W ENE NNE WNW G
NE NE E S ESE S SW SW SSW S WSW SSW SSW SSW SW SW W SW ENE ENE E E SSE ENE W SSW SSW SSW SSE SW W K
Marine Pit, Glyn & S. Wales
Abercarn & S. Wales
Thornwell & S. Wales
270 deaths.
WSW SW SW SW E NNE WNW ENE NW SW SW WSW SW W S W WSW WSW W NW SW SE WNW ENE W WNW W WNW NE NE Glasgow noon
W W SSW ESE E SW SSW W W NNW W NNW W SW WNW SW W WSW NW NW SSW SW NW SSW W WSW WSW WSW WSW Kew noon

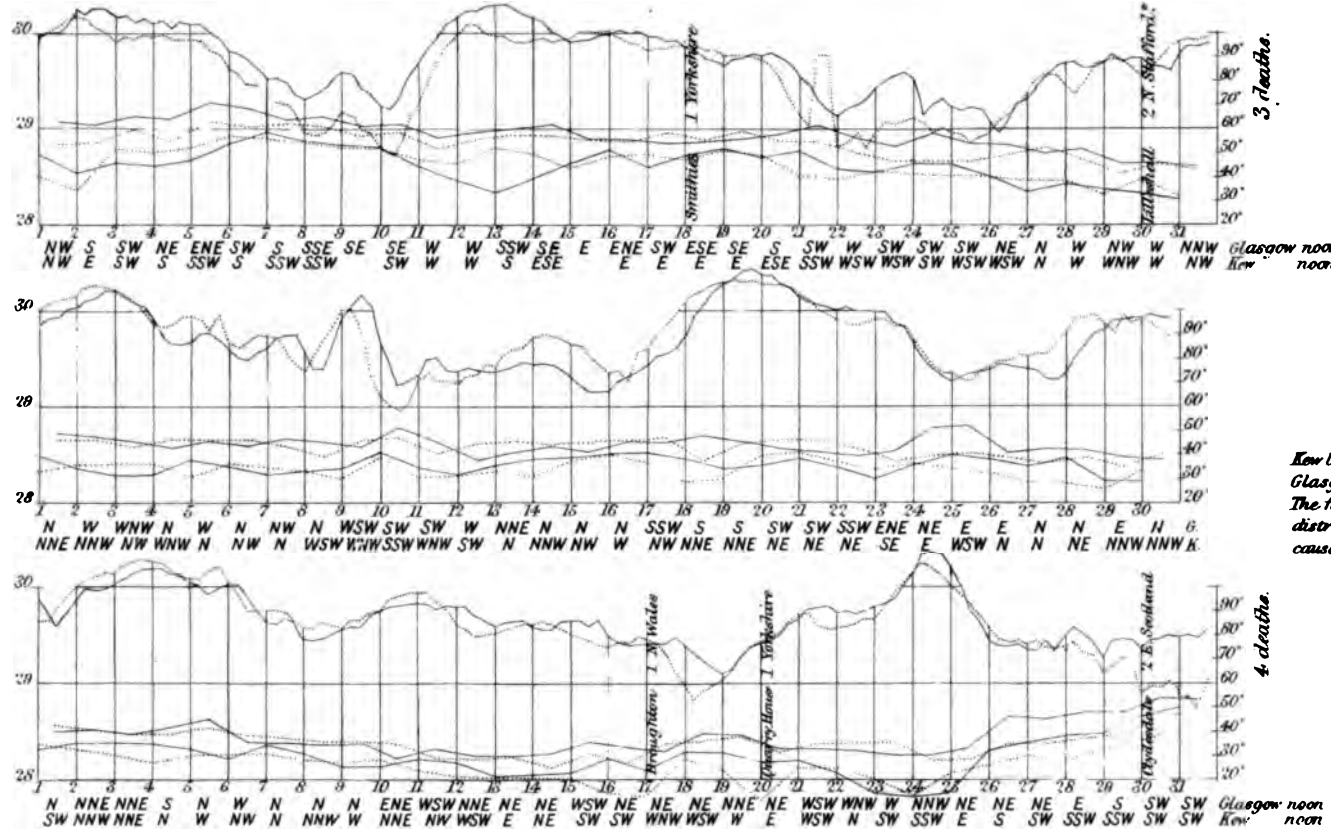
Kew lines are firm
Glasgow " dotted
The figures attached to the districts shew the N° of deaths caused by the explosions.

The firm top line is the Barometer reading at Kew taken 4 a.m. 10 a.m. 4 p.m. & 10 p.m.
The dotted top line is the Barometer reading at Glasgow taken do. do. do. do.
The lower lines are the Maxima and Minima temperatures at Kew & Glasgow observed respectively at 10 a.m. & 10 p.m.

Proceedings N° E.1 of M&ME. 1878-79.

Ind^e Prod. Newcastle

DIACRAM SHEWING THE HEICHT OF THE BAROMETER, THE MAXIMA & MINIMA TEMPERATURES & THE DIRECTION OF THE WIND AT THE OBSERVATORIES of KEW & GLASGOW TOGETHER WITH THE EXPLOSIONS OF FIREDAMP IN ENGLAND & SCOTLAND.


30
29
28
90°
80°
70°
60°
50°
40°
30°
20°
1 Yorkshire
Smithills
2 N. Staffords.
Talkwhall
3 deaths.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
NW S SW NE ENE SW S SSE SE SE W W SSW SE E ENE SW ESE SE S SW W SW SW SW NE N W NW W NNW Glasgow noon
NW E SW S SSW S SSW SSW SW W W S ESE E E E E ESE SSW WSW WSW SW WSW WSW N W WNW W NW Kew noon
N W WNW N W N NW N WSW WSW SW SW W NNE N N N SSW S S SW SW SSW ENE NE E E N N E N 6.
NNE NNW NW WNW N NW N WSW WSW SSW WNW SW N NNW NW W NW NNE NNE NE NE NE SE E WSW N N NE NNW NNW K.
1 N. Wales
Broughton
1 Yorkshire
Worsley Mesnes
2 E. Scotland
Hyndmarsh
4 deaths.
N NNE NNE S N W N N N ENE WSW NNE NE NE WSW NE NE NE NNE NE WSW WNW W NNW NE NE NE E S SW SW Glasgow noon
SW NNW NNE N W NW N NNW W NNE NW WSW E NE SW SW WNW WSW W E WSW N SW SSW E S SW SSW SSW SW SW Kew noon

Kew lines are firm.
Glasgow .. dotted.
The figures attached to the districts shew the N° of deaths caused by the explosions.

The firm top line is the Barometer reading at Kew taken 4 a.m. 10 a.m. 4 p.m. & 10 p.m.
The dotted top line is the Barometer reading at Glasgow taken do. do. do. do.
The lower lines are the Maxima and Minima temperatures at Kew & Glasgow observed respectively at 10 a.m. & 10 p.m

And[w] Reid, Newcastle

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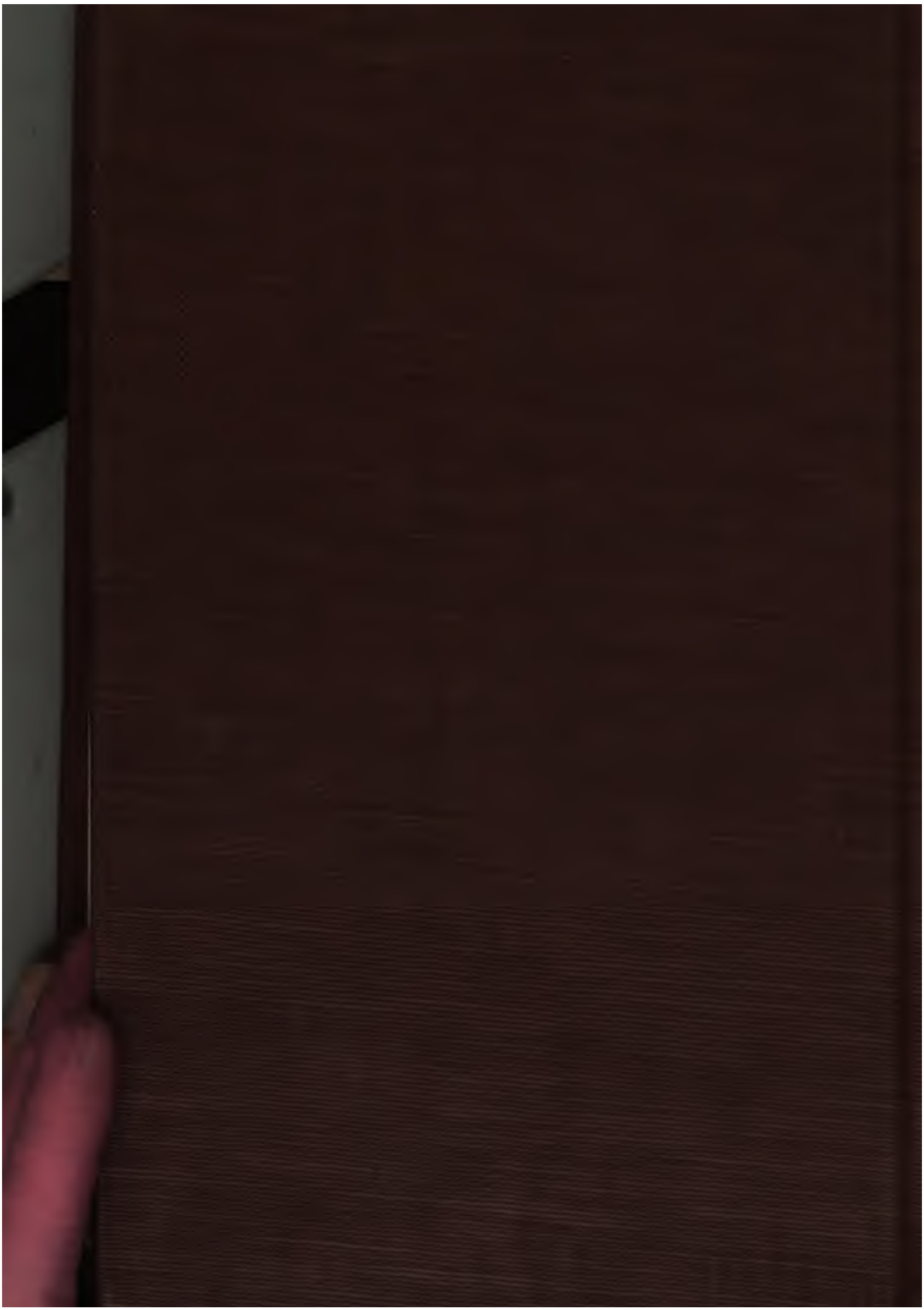
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